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NACA

RESEARCH MEMORANDUM

for the

Air Materiel Command, U. S. Air Force

and

Bureau of Aeronautics, Department of the Navy

COMPILATION AND REVIEW OF EFFECTS OF DESIGN PARAMETERS ON DITCHING CHARACTERISTICS

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Langley Field, Va.

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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

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RESEARCH MEMORANDUM

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SUMMARY

This paper supplements a previously published one on the effect of design parameters on ditching characteristics. The supplementary information is based on additional data available from both model tests and full-scale experience. In addition, summary tables compiled from the NACA model ditching investigations are presented.

INTRODUCTION

A summary of available information on effects of design parameters on the ditching characteristics of aircraft was given in reference 1. Since that time, a large number of additional model investigations of later airplane types has been made and further full-scale experience has been gained. At the recommendation of the NACA Subcommittee on Seaplanes, a compilation of this more recent information has been made to bring the original summary up to date.

This paper presents a bibliography of the papers of all the model ditching investigations conducted by NACA (references 2 to 38) and a summary of generalized results to supplement that of the first paper. In addition, summary tables of pertinent data from the references are included to assist in preliminary evaluations of similar configurations.

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NACA MODEL DITCHING INVESTIGATIONS

The airplanes investigated may be divided into three general categories: bombers, fighters, and transports. For convenience, the references and summary tables are grouped alphabetically and numerically according to these types as follows:

Airplane	Reference	Table
Bombers:		
A-20	2,3,38	I
A-26	4	II
B-17	5,38	III
B-24	6,7,8,38	IV
B-25	9,38	V
B-26	10,38	VI
B-29	11,12	VII
B-32	13	VIII
B-35	14	IX
B-36	15	X
B-45	16,17	XI
B-47	18	XII
PV	19	XIII
P2V	20,37	XIV
P4M	21	XV
SB2C	22	XVI
TBF	Unpublished	XVII
TBU	Unpublished	XVIII
Fighters:		
FJ	23	XIX
F6U	24	XX
F-86	25	XXI
F9F	26	XXII
P-38	27	XXIII
Transports:		
Constellation	28,29,37	XXIV
Convair-Liner	30	XXV
C-82	31	XXVI
C-124	32	XXVII
C-125	33	XXVIII
DC-4	34,37	XXIX
DC-6	34	XXX
R6O	35	XXXI
Stratocruiser	36	XXXII

The information in the summary tables is based on calm-water landing tests. In rough-water landings made parallel to waves or swells, the same general type of performance should be obtained. However, in ditchings made perpendicular to waves more damage and violence of motion may occur, depending on the choice of ditching site and the size and portion of the wave contacted. Each table is referenced to the NACA papers on the subject. The symbols used in the tables are defined as follows:

	parts removed to simulate damage
	scale-strength sections
	section crumpled to simulate damage
*	recommended ditching attitude and flap setting
b	ran deeply - the model settled deeply into the water with little change in attitude
d_1	dived violently - the model stopped abruptly in a nose-down attitude with the majority of the model submerged
d_2	dived slightly - the model stopped abruptly in a nose-down attitude with the nose of the model submerged
f	flipped over - the model rotated about the transverse axis and stopped in an inverted position
h	ran smoothly - the model made a very stable run
o	oscillated - the model oscillated about the longitudinal or vertical axis
p	porpoised - the model undulated about the transverse axis with some part of the model always in contact with the water
s	skipped - the model cleared or rebounded from the water
t	turned sharply - the model pivoted quickly about a vertical axis
u	trimmed up - the attitude of the model increased while running in the water

AIRPLANE TYPES

Bombers

The model ditching investigations of bomber airplanes are reported in references 2 to 22 and are summarized in tables I to XVIII. Bomber airplanes have weak bomb-bay doors that usually experience extensive damage. Sometimes this damage causes violent behavior, but, whether violent behavior occurs or not, safe ditching stations in the aft fuselage are almost an impossibility due to the rush of water through the airplane when damage occurs. Consequently, the survival rate for bomber ditchings is relatively low. Because of the low survival rate bombers as a class cannot be considered to have acceptable characteristics.

Fighters

The model ditching investigations of fighter airplanes are reported in references 23 to 27 and are summarized in tables XIX to XXIII. Fighter airplanes frequently make dangerous motions in a ditching but the survival rate in fighter ditchings is relatively high. The fuselage structure is strong and the pilot generally can be well-braced for taking accelerations. The bottom skin is sometimes damaged badly but the frame remains more or less intact and there is little water flow through the pilot's compartment.

Transports

The model ditching investigations of transport airplanes are reported in references 28 to 36 and are summarized in tables XXIV to XXXII. Transport airplanes have marginal strength fuselages; that is, their bottoms experience some damage in ditchings but usually are not demolished. Their fuselage bottoms are stronger than bombers because there are fewer doors in the bottom and the requirements for cargo floors and pressurized cabins contribute to the strength. Because of the large number of passengers involved and their general lack of training in ditching procedures it would seem that the ditching requirements for transports should be more severe than for other types of airplanes. In general, transports make fair ditchings but need stronger fuselage bottoms.

GENERAL ARRANGEMENT

Wing

The discussion of wing location in reference 1 covers most of the wing configurations now in wide use except the very thin wing, the sweptback wing, and the flying wing. There are no indications that thin wings cause any changes in ditching behavior other than the obvious effect on buoyancy. Sweepback has had very little influence on ditching, except in the aerodynamic influences on handling and landing characteristics and in the location of nacelles, auxiliary fuel tanks, and so forth when attached to the wing. The flying wing appears to have reasonably good ditching characteristics except for its susceptibility to damage (see reference 14). No violent motions are likely even though damage occurs, but safe ditching stations will be difficult to find.

Flaps

The landing flaps have had a noticeable hydrodynamic effect on about 25 percent of the models tested. In most of these cases there was only a slight nose-down moment observed and in no case was a flaps-up condition preferred. For certain models, a flaps-down condition caused diving, but with the flaps retracted and with the corresponding increase in speed the damage and acceleration were even more severe than in the dives. For airplanes having very low wings the manner in which the flaps failed, that is, whether they were completely torn from the wing or whether the linkage failed so that the flaps were free to rotate toward a neutral position, has an effect on the results (in reference 30 a flap merely rotating toward a neutral position was occasionally detrimental). It is preferred to have flaps down in a ditching in order to obtain a low forward speed and so decrease fuselage damage but the flaps should be weak enough to fail without producing an undesirable moment (ultimate strength less than about 300 lb/sq ft).

Engine Installation

The effects of various engine locations are discussed in reference 1. Since that time, a greater variety of engine arrangements have been used due to the advent of jet propulsion. One installation has employed jet engines in nacelles mounted on struts below the wing (see reference 18). The results of the model tests indicate that very likely such engines will be torn off in a ditching. There was, however, little difference in behavior when the nacelles broke off and when they did not. Nevertheless, when the nacelles were removed before testing, the runs were longer and smoother than in the landings with nacelles installed.

Fighter airplanes usually have jet engines located within the fuselage. In such installations the location of the air intake is the important factor affecting ditching. The inlets cause detrimental behavior when a ditching is made at low enough attitude to get them in the water at high speeds. Usually, however, an airplane can be landed so that the inlets will be held clear of the water until a fairly slow speed is reached. (See references 23 to 26.)

Jet engines mounted on the wing (see reference 16) or turbo-propeller engines mounted similarly will have about the same effect as a standard reciprocating-engine nacelle (see reference 1) except that they are smaller and have less water drag. Pusher-propeller engines installed on the wing (see reference 15) also have low water resistance but the water drag of current engine nacelles is not an important parameter. Tests have not yet been made of engines slung under the fuselage, but such installations appear to be undesirable from the ditching viewpoint because of the "water brake" effect and consequent diving moments that would be present.

Tail Surfaces

The location of the tail surfaces has not previously been considered to influence ditching behavior. Unpublished model data, however, indicate that the horizontal-tail location affects the attitude at which the airplane will run on the water. If the horizontal tail is located very high on the vertical fin the model will, when there is a tendency to trim up, trim higher than if the horizontal tail is in a low position. Sometimes the horizontal tails broke in the model tests but no changes in behavior due to this damage were noted (see reference 15). In these cases, however, the tail surfaces were never completely torn away and the remaining parts offered enough resistance to entering the water to prevent the fuselage from going any deeper.

Landing Gear

The effects on ditching of conventional arrangements for landing wheels are discussed in reference 1. Another arrangement, the bicycle gear, is now also being used. This type of gear necessitates doors in the fuselage bottom which from the ditching viewpoint are undesirable unless they are much stronger than usual.

In model tests of one airplane employing the bicycle landing gear it was found that the main-wheel doors would fail (see reference 18).

In this case no detrimental behavior occurred but of course the fuselage was flooded. The outrigger wheels contributed no difficulties to ditching. A contribution of the bicycle-gear design favorable to ditching is a very strong fuselage structure. The fuselage of some airplanes has broken apart near the wing when ditched but is is unlikely that a fuselage strong enough to support a bicycle landing gear would break in this manner.

Recent model investigations (see references 26 and 33) have added to the accumulation of data indicating the undesirability of a wheels-down ditching. In both cases an extended landing gear caused diving.

FUSELAGE CHARACTERISTICS

Bottom Strength

The strength of the bottom of the fuselage is probably the most important factor influencing ditching behavior. Most airplanes would ditch well if the fuselage bottom did not experience damage, but usually considerable damage occurs.

The transports generally have the strongest fuselage bottoms with an average strength in resistance to water loads, as estimated by manufacturers, of 8 to 12 pounds per square inch. There is a wide variation in the bottom strength of fighter airplanes based on data obtained from manufacturers. Some have bottom strengths as low as 2 pounds per square inch while others have parts of the bottom as strong as 40 pounds per square inch. Bombers generally have very weak bottoms with the bomb-bay doors especially weak. The ultimate strength of bomb-bay doors is usually about 1/2 to 2 pounds per square inch. The fuselage bottoms are usually somewhat stronger than the doors but manufacturers estimates indicate the bottoms of bombers to be weaker than those of transports.

Reference 1 discusses some of the difficulties of obtaining bottoms that will not fail in a ditching and suggests the desirability of obtaining designs that will minimize the danger to personnel if bottom damage occurs. Possible methods of reducing the need for greater bottom strength are suggested in reference 1 and in this paper under the heading of "Ditching Aids."

The middle third of the fuselage length has been called the critical region (see reference 1) because of susceptibility to damage and the consequent effect on behavior. In recent model investigations approximately scale strength bottoms have been used to determine the location and amount of possible bottom damage. In these tests most of the damage usually occurred in this middle third, substantiating it as the critical region.

Shape

Aft of the center of gravity.- Some current airplanes have large amounts of sweep-up on the aft part of the fuselage. This high degree of longitudinal curvature causes a suction and the models trim up in the water (see reference 36). Recent unpublished investigations indicate that high cross-section curvature on the aft fuselage also causes suctions and motions much the same as those produced by high longitudinal curvature. Trimming up is not necessarily detrimental but could contribute to undesirable results as pointed out in reference 1. A bottom with little curvature (both longitudinal and cross-sectional curvature) tends to decrease trimming up but is undesirable because of the accompanying high water loads. There are indications that low cross-sectional curvature in combination with high longitudinal curvature tends to cause skipping. (See references 23 and 31.) Consequently, moderately curved sections appear to be best both from the stability and the load points of view.

Forward of the center of gravity.- In reference 1 it was concluded that the differences in the ratio of fuselage length forward of the center of gravity to the total length gave no consistent differences in the hydrodynamic performance. Recent trends in fighter design have led to increases in this ratio from approximately 1/4 to 1/2. There is evidence that the increase in bow length has been advantageous to fighter airplanes because there is less diving or nosing-in tendency. For bombers the increase in ratio has been small and there is little noticeable effect on behavior.

Bow curvature also has an influence on behavior. A bow that is more or less straight on the bottom but curves up abruptly at the nose will offer less restoring moment and thus be more likely to dive than one that curves up gradually. The desirability of the gradually curved up bow has been substantiated by brief unpublished model tests in which a dive was produced by adding the bow shown in figure 1.

The effect of bow cross-sectional curvature has not been investigated but on the same basis as for aft fuselage cross-section curvature it appears probable that a moderately curved cross section would be most desirable.

Size

The physical magnitude of airplanes appears to have an effect on the degree of violence of ditching behavior. Small differences cannot be differentiated but in the over-all range from fighters to large bombers and transports the effect of size and pitching moment of inertia is apparent. As the physical magnitude of airplanes increases the ditching behavior becomes less violent.

Interior Arrangement

Effect on hydrodynamic performance.- Probably the item in interior arrangement that has the greatest influence on hydrodynamic performance is the bulkhead just aft of a bomb bay. Bomb-bay doors usually fail so this bulkhead is immediately subjected to water loads. In references 16 and 19 diving was prevented by removing this bulkhead and the part of the fuselage bottom that might be torn away if the bulkhead failed. In reference 6 removing the bulkhead or part of the bulkhead reduced the severity of diving. Of course, there were numerous cases in which the bomb-bay doors failed and diving was not produced so in these cases the bulkhead caused no detrimental behavior but offered some protection to the interior of the aft fuselage.

Safe location of personnel.- Reference 1 contains a detailed discussion of the effect of interior arrangement on safe locations for ditching positions. There are a few points, however, that should be added. Available records indicate that the survival rate for fighter pilots is higher now than at the time of reference 1. Although the behavior of current fighter airplanes is less severe, a more important factor may be the current increase in use of the safety harness. In bomber and transport airplanes the pilot's compartment is also a relatively safe ditching station. The compartment is usually high so it does not flood quickly except in a dive; damage is not severe, and escape hatches are available.

The most dangerous ditching station in a bomber airplane appears to be aft of the bomb bay because of the likelihood of a large inrush of water through the low-strength bomb-bay doors and the probable failure of the bulkhead just aft of the bomb bay.

In a transport airplane the situation is different. The fuselage generally has no predominantly weak part such as bomb-bay doors and the passenger compartment floor is more substantial than the bomber's floor. Consequently, the aft part of the fuselage is possibly no more hazardous than any other part. In those transports which have double decks (see references 35 and 36) the upper deck offers the greatest safety. The most hazardous type of transport, as far as ditching stations are concerned, is the "flying boxcar" type (see references 31 and 33). In this type of airplane, with its large doors and wide flat bottom with accompanying high water pressures, some damage is very probable. The high wing of this type affords no buoyancy until the airplane sinks deeply; consequently, the cargo or passenger compartment is likely to be flooded to such an extent as to be extremely hazardous.

Escape hatches.- More thought should be given, in all types of airplanes, to the problem of obtaining sufficient escape hatches in the upper part of the fuselage. These hatches should be positioned for exit onto the wing or directly to a life raft. Such exits are not usually available in sufficient number, especially in transports, to permit a rapid escape of a full load of passengers.

Protuberances

The usual protuberances such as radiators, turrets, antennas, and so forth are discussed in reference 1. Recent airplane developments have brought additional protuberances.

Cargo container.- Model investigations (see reference 29) indicate no detrimental effect due to the Constellation Speedpak; in fact, it was beneficial because of the protection it afforded the bottom of the airplane. The construction of the Speedpak was such that it caved in on contact with the water and thus acted as a shock absorber.

External fuel tanks.- The need for greater fuel storage in jet-propelled airplanes has resulted in the use of external fuel tanks. The usual type has been the wing-tip tank, but on airplanes with swept wings the external tank may be located under the wing instead of at the tip. Tanks under the wing probably will be detrimental in a ditching because of the added hydrodynamic drag and the fact that their shape is such that they will produce a suction force. Model tests (see reference 25) involving auxiliary fuel tanks attached under the wing substantiate this result. Wing-tip tanks probably will not be detrimental since they will not enter the water until a low speed is reached and if empty will offer additional buoyancy (see references 23 and 26).

DITCHING AIDS

If the use of an airplane is such that a high degree of ditching safety is required, a ditching aid may be the best method of insuring such safty. If a ditching aid is designed as an integral part of the airplane in the early stages of design it possibly could be obtained with little or no penalty in performance. Reference 1 describes various ditching aids such as hydroflaps, hydrofoils, hydro-scoops, and floating gear.

Hydro-Ski

Another possibility for a ditching aid is a planing surface that can be extended on struts so that in a landing the airplane rides on the planing surface with the main body of the airplane not subjected to high water loads at landing speeds. Such a device has been called a hydro-ski (see reference 37). Almost any degree of effectiveness is possible with a hydro-ski ditching aid and the hazardous motions and structural damage associated with ditching can be eliminated. For a bomber airplane twin skis retracting into the side of the fuselage or into the wings could be used. For airplanes with bottoms such as transports a single ski retracting into the bottom would be practical or twin skis could be employed.

Speed Brake

Certain types of airplanes require speed brakes or dive brakes. These devices assume various forms one of which is approximately a flat plate hinged at its leading edge and opening outward on the bottom of the fuselage. A few airplanes have had this type of brake located forward of the center of gravity. Such a device possibly could be located so that it would serve as a hydroflap (a type of ditching aid described in reference 1) as well as a speed brake. So far speed brakes have not been located far enough forward of the center of gravity to be in the most advantageous location for a hydroflap and the strength of the brakes is not great enough for use as a hydroflap. Model investigations (reference 26) show the possibility of such a brake as a ditching aid if these requirements are met.

CONCLUDING REMARKS

Because of performance requirements and the relatively low frequency of emergency landings even in wartime, it is unlikely that airplanes will ever be designed specifically for "safe" ditchings. It appears possible, however, to reduce the hazards by some attention to the effects of design parameters such as those outlined. It may also in certain cases prove possible to incorporate ditching aids to keep peak water loads off the structure without significant performance penalties. These possibilities together with the establishment of proper approach procedures, provision of adequate means of escape, and early rescue remain the most effective means of increasing survival rates from future ditching accidents.

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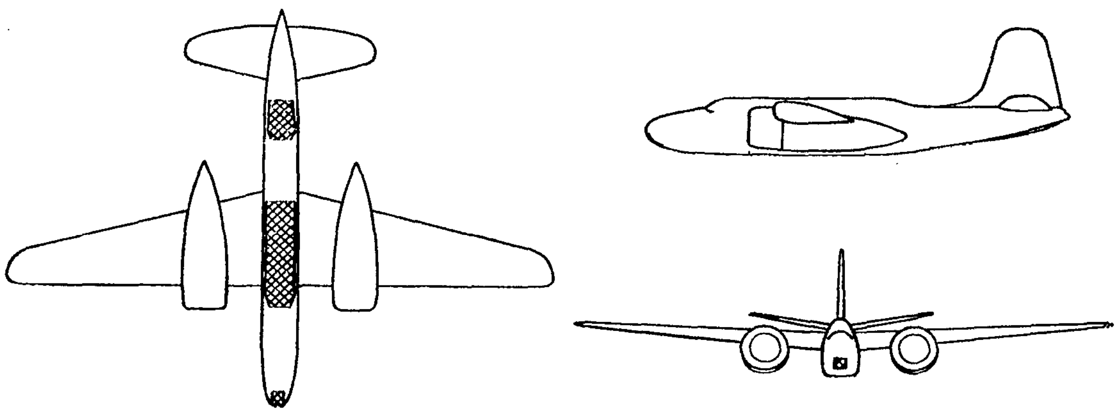
TABLE I

SUMMARY OF MODEL DITCHING INVESTIGATION OF DOUGLAS A-20 AIRPLANE

[Model scale, $\frac{1}{10}$; gross weight, 21,500 lb; center-of-gravity location, 28 percent M.A.C., all values full scale]

Damage simulated by removal of sections (shaded areas on three view)



Landing attitude (deg)	Flap setting (deg)	Landing speed (knots)	Length of run (ft)	Maximum longitudinal deceleration (g)	Average longitudinal deceleration (g)	Motions of model
Undamaged model						
2	0	104	200	-	2 1/2	u h
2	40	104	200	-	2 1/2	u h
6	0	104	400	-	1	u h
6	40	87	200	-	1 1/2	u h
10	0	87	350	-	1	u h
10	40	69	200	1 1/2	1	u h
Damaged model						
2	40	104	150	5 1/2	3	b
* 10	40	69	100	3	2	b

REMARKS

Simulation of damage on this model stopped the trimming up tendency and caused the model to run deeper in the water. The large nacelles caused violent turns when the model was ditched wing low. (See references 2, 3, and 38.)

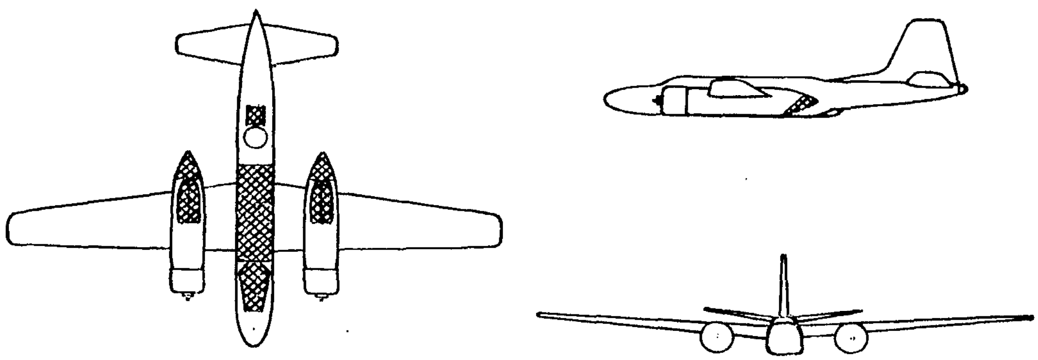
TABLE II

SUMMARY OF MODEL DITCHING INVESTIGATION OF DOUGLAS A-26 AIRPLANE

[Model scale, $\frac{1}{12}$; gross weight, 25,730 lb; center-of-gravity location, 28 percent M.A.C.; all values full scale]

(a) Without hydroflap

Damage simulated by removal of sections (shaded areas on three view)



Landing attitude (deg)	Flap setting (deg)	Landing speed (knots)	Length of run (ft)	Maximum longitudinal deceleration (g)	Average longitudinal deceleration (g)	Motions of model
Undamaged model						
3	55	102	400	2	1	s d_1
3	55	102	400	3	1	s t
8	0	115	600	4 1/2	1	s t
8	55	96	500	-	1	h
13	0	102	250	8	2	d_1
13	55	90	150	5	2 1/2	d_1
Damaged model						
3	55	101	100	-	4 1/2	d_1
8	0	115	250	6 1/2	2 1/2	d_1
*8	55	86	100	-	3 1/2	d_1
13	0	102	250	-	2	d_1
13	55	86	150	-	2	d_1

NACA

REMARKS

The behavior of the model was exceptionally violent. Violent dives were even obtained with the model undamaged. In general the dives obtained at the 8° attitude were less violent than those obtained at the 13° attitude. When ditched with one wing slightly low the large nacelles would dig in the water and cause sharp turns. (See reference 4.)

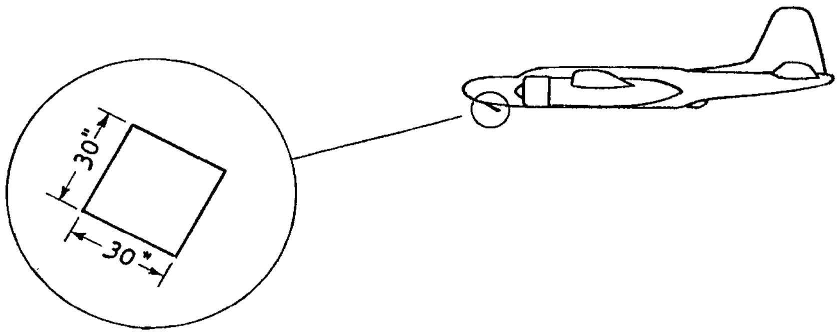
TABLE II

SUMMARY OF MODEL DITCHING INVESTIGATION OF DOUGLAS A-26 AIRPLANE - Concluded

[All values full scale]

(b) With hydroflap

Damage as shown on three view. All-purpose nose door (open at an angle of 30° to thrust line) used as hydroflap.



Landing attitude (deg)	Flap setting (deg)	Landing speed (mph)	Length of run (ft)	Maximum longitudinal deceleration (g)	Average longitudinal deceleration (g)	Motions of model
3	55	101	300	-	2	p
* 8	55	86	250	3 1/2	1 1/2	p
13	55	86	200	-	1 1/2	p

REMARKS

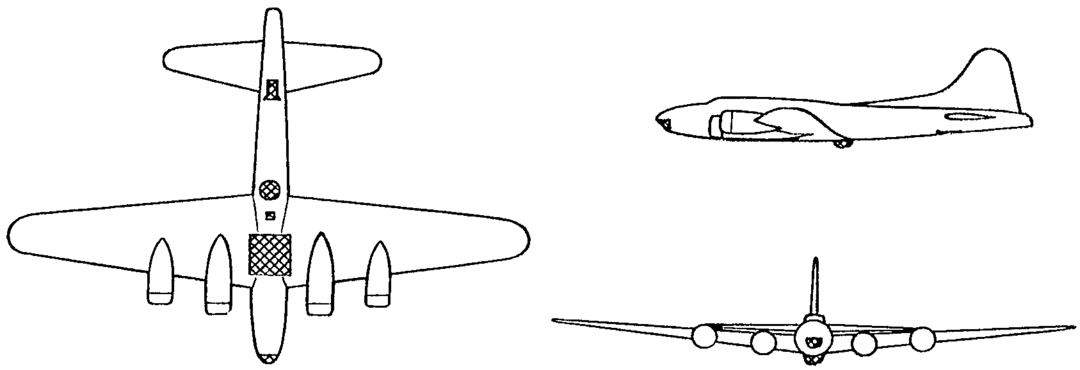
Rather violent porpoising runs were obtained with the hydroflap, but these runs were considerably better than the violent dives obtained with the standard airplane. (See reference 4.)

TABLE III

SUMMARY OF MODEL DITCHING INVESTIGATION OF BOEING B-17 AIRPLANE

[Model scale, $\frac{1}{16}$; gross weight, 57,000 lb; center-of-gravity location, 30 percent M.A.C.; all values full scale]

Damage simulated by removal of sections (shaded areas on three view)



Landing attitude (deg)	Flap setting (deg)	Landing speed (knots)	Length of run (ft)	Maximum longitudinal deceleration (g)	Average longitudinal deceleration (g)	Motions of model
Undamaged model						
0	45	122	-	7	-	d_1
3 1/2	45	104	-	-	-	d_1
7	0	104	-	8	-	d_1
7	45	87	-	6 1/2	-	t d_1
10	0	87	-	-	-	d_1
10	45	87	-	-	-	d_1
Damaged model						
0	45	122	-	7 1/2	-	t
3 1/2	45	104	-	-	-	t s
* 7	45	87	-	-	-	s
10	45	87	-	-	-	p

REMARKS

The tests indicated that the lower turret was the principal cause of the diving. It was recommended that this turret be made easily jettisonable. (See references 5 and 38.)

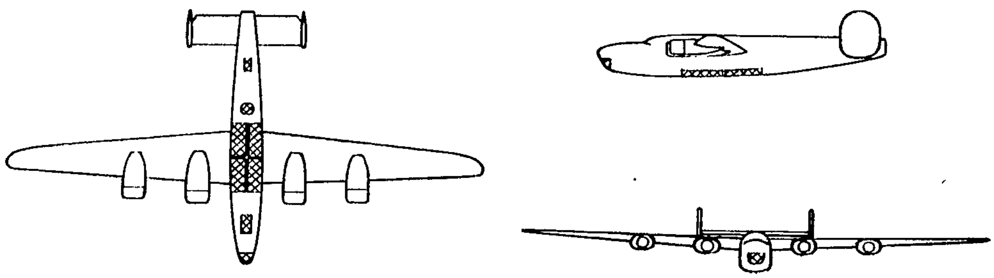
TABLE IV

SUMMARY OF MODEL DITCHING INVESTIGATION OF CONSOLIDATED B-24 AIRPLANE

[Model scale, $\frac{1}{16}$; gross weight, 48,500 lb; center-of-gravity location, 30 percent M.A.C.; all values full scale]

(a) Without hydroflap

Damage simulated by removal of sections (shaded areas on three view)



Landing attitude (deg)	Flap setting (deg)	Landing speed (knots)	Length of run (ft)	Maximum longitudinal deceleration (g)	Average longitudinal deceleration (g)	Motions of model
Undamaged model						
1	40	104	550 900	1 1/2 2 1/2	1 1/2	h s
5	0	104	950 800	1 1	1/2 1/2	s p
5	40	87	600 550	1 1/2 1 1/2	1/2 1/2	h p
9	0	87	300	3	1	h
9	40	87	250 550	3 1/2 -	1 1/2 1/2	h p
Damaged model						
1	40	104	200 300	- -	2 1/2 1 1/2	d_1 s
* 5	40	87	250	-	1 1/2	p d_1
9	40	87	150	-	2	d_1

REMARKS

The bomb-bay doors on this airplane are exceptionally weak and will probably fail in a ditching. The model tests indicated that failure of the bomb-bay doors caused a diving moment. The amount of damage to the bulkhead aft of the bomb bay would determine the severity of the behavior of the airplane. (See references 6 through 8.)

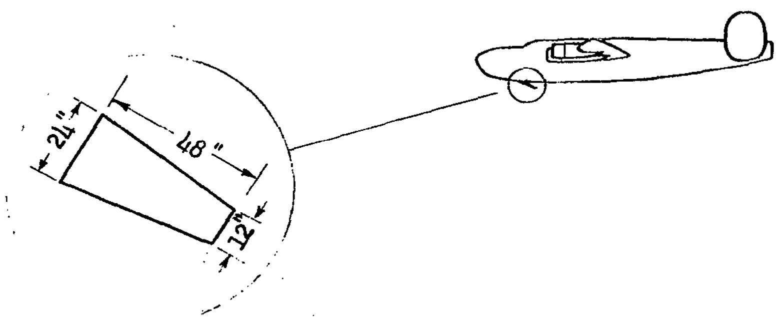
TABLE IV

SUMMARY OF MODEL DITCHING INVESTIGATION OF CONSOLIDATED B-24 AIRPLANE - Concluded

[All values full scale]

(b) With hydroflap

Damage same as shown on three view. Hydroflap as indicated below.



Landing attitude (deg)	Flap setting (deg)	Landing speed (knots)	Length of run (ft)	Maximum longitudinal deceleration (g)	Average longitudinal deceleration (g)	Motions of model
1	40	104	450	-	1	p
6	40	87	300	-	1	p
9	40	87	350	-	1	p

REMARKS

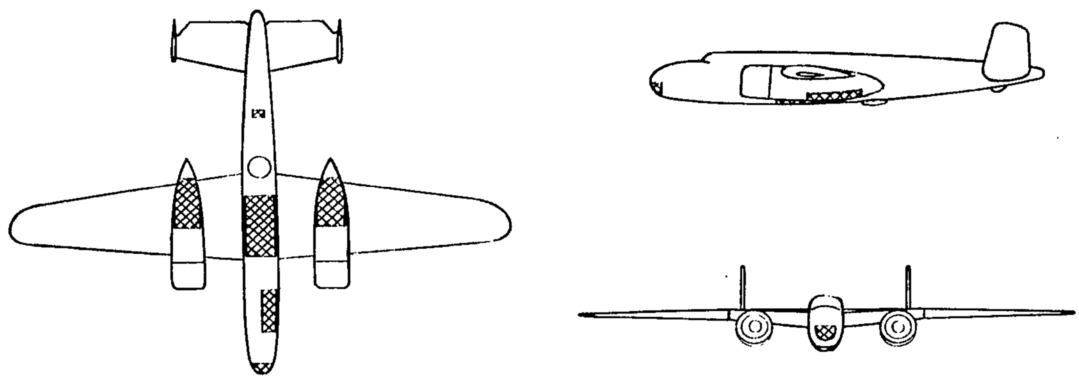
Several ditching aids that would improve the behavior were investigated on this model. The hydroflap was considered the most practical. (See references 6, 7, 8, and 38.)

TABLE V

SUMMARY OF MODEL DITCHING INVESTIGATION OF NORTH AMERICAN B-25 AIRPLANE

[Model scale, $\frac{1}{11}$; gross weight, 26,000 lb; center-of-gravity location, 25 percent M.A.C.; all values full scale]

Damage simulated by removal of sections (shaded areas on three view)



Landing attitude (deg)	Flap setting (deg)	Landing speed (knots)	Length of run (ft)	Maximum longitudinal deceleration (g)	Average longitudinal deceleration (g)	Motions of model
Undamaged model						
0	0	104	200	3 1/2	2 1/2	h
0	45	104	250	4	2	t
6	0	104	250	3	2	h
6	45	87	150	3	2	h
12	0	104	300	3	1 1/2	h
12	45	87	200	3 1/2	1 1/2	h
Damaged model						
0	45	104	350	2 1/2	1 1/2	s
6	45	87	250	3	1 1/2	b
* 12	45	87	150	3 1/2	2	b

REMARKS

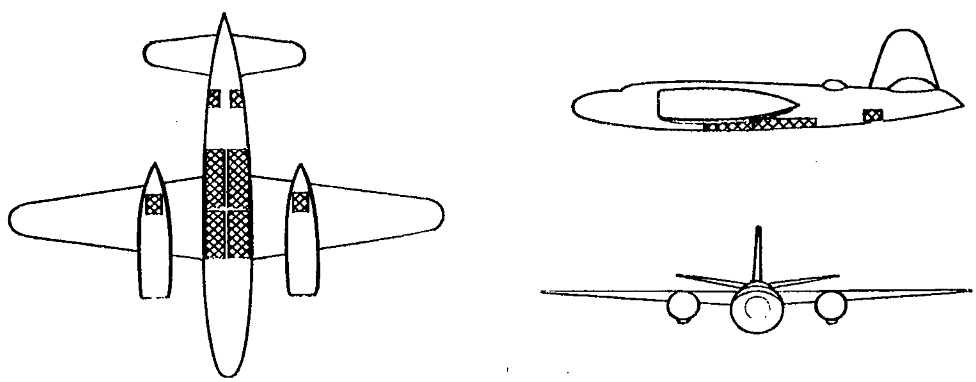
The performance of the model was not appreciably changed by simulation of damage. The model ran deeper in the water with the parts removed, but the behavior in general was similar. The large nacelles tended to cause violent turns when one wing was low. (See references 9 and 38.)

TABLE VI

SUMMARY OF MODEL DITCHING INVESTIGATION OF MARTIN B-26 AIRPLANE

[Model scale, $\frac{1}{12}$; gross weight, 31,000 lb; center-of-gravity location, 14 percent M.A.C.; all values full scale]

Damage simulated by removal of sections (shaded areas on three view)



Landing attitude (deg)	Flap setting (deg)	Landing speed (knots)	Length of run (ft)	Maximum longitudinal deceleration (g)	Average longitudinal deceleration (g)	Motions of model
Undamaged model						
-1	0	122	400	-	1 1/2	uh
-1	55	104	400	2	1	uh
6	0	104	350	-	1 1/2	uh
6	55	104	350	-	1 1/2	us
13	0	104	300	-	1 1/2	h
13	55	104	350	2	1 1/2	h
Damaged model						
-1	55	104	400	3	1	s
* 6	55	104	350	4	1 1/2	s
13	55	104	300	6	1 1/2	s

NACA

REMARKS

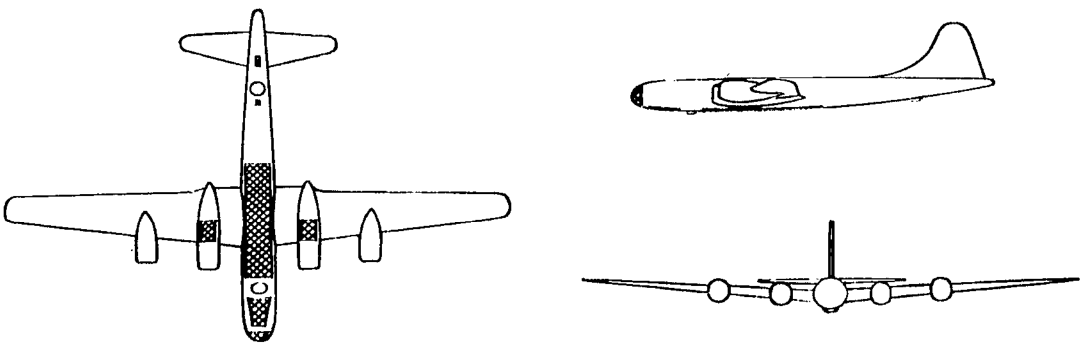
The model had a trimming up tendency in the undamaged condition. The large nacelles caused sharp turns when the model was ditched wing low. (See references 10 and 38.)

TABLE VII

SUMMARY OF MODEL DITCHING INVESTIGATION OF BOEING B-29 AIRPLANE

[Model scale, $\frac{1}{20}$; gross weight, 105,000 lb; center-of-gravity location, 25 percent M.A.C.; all values full scale]

Damage simulated by removal of sections (shaded areas on three view)



Landing attitude (deg)	Flap setting (deg)	Landing speed (knots)	Length of run (ft)	Maximum longitudinal deceleration (g)	Average longitudinal deceleration (g)	Motions of model
Undamaged model						
1	45	122	250	8	2 1/2	d_1
5	45	104	650	1	1/2	h
9	0	122	850	2	1	h
9	45	87	450	1	1/2	h
13	0	104	700	2	1/2	h
13	45	87	200	1 1/2	1 1/2	d_2
Damaged model						
1	45	122	600 200	- -	1 3 1/2	p d_1
5	45	104	350	-	1 1/2	p
* 9	45	87	300	-	1	h
13	45	87	250	-	1 1/2	h

REMARKS

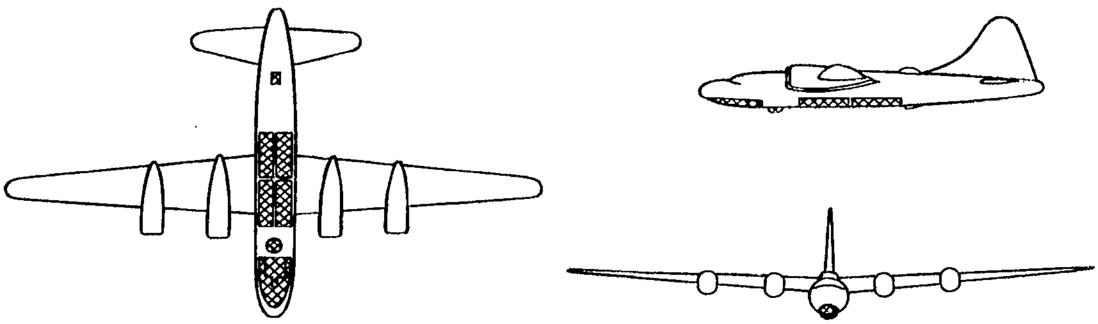
The scale-strength landing flaps on the model did not fail consistently. When the flaps did not fail the model usually dived. (See references 11 and 12.)

TABLE VIII

SUMMARY OF MODEL DITCHING INVESTIGATION OF CONSOLIDATED B-32 AIRPLANE

[Model scale, $\frac{1}{20}$; gross weight, 100,000 lb; center-of-gravity location, 30 percent M.A.C.; all values full scale]

Damage simulated by removal of sections (shaded areas on three view)



Landing attitude (deg)	Flap setting (deg)	Landing speed (knots)	Length of run (ft)	Maximum longitudinal deceleration (g)	Average longitudinal deceleration (g)	Motions of model
Undamaged model						
0	40	122	550	1 1/2	1	u h b
6	40	102	500	2	1	u h b
13	0	115	600	2	1	h b
13	40	88	450	1 1/2	1	h b
Damaged model						
0	40	122	450	4	1 1/2	p b
* 6	40	102	350	4 1/2	1 1/2	h b
13	40	88	400	3 1/2	1	h b

NACA

REMARKS

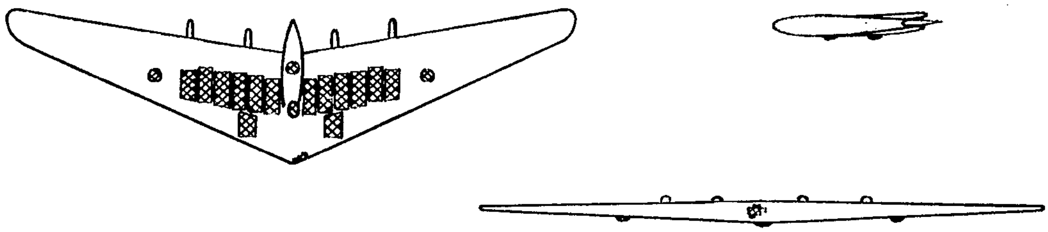
Decelerations were increased when damage was simulated, but the behavior of the model was not appreciably changed. (See reference 13.)

TABLE IX

SUMMARY OF MODEL DITCHING INVESTIGATION OF NORTHROP B-35 AIRPLANE

[Model scale, $\frac{1}{20}$; gross weight, 150,000 lb; center-of-gravity location, 25 percent M.A.C.; all values full scale]

Damage simulated by removal of sections (shaded areas on three view)



Landing attitude (deg)	Flap setting (deg)	Landing speed (knots)	Length of run (ft)	Maximum longitudinal deceleration (g)	Average longitudinal deceleration (g)	Motions of model
Undamaged model						
9	50	111	400	-	1 1/2	h t p t
Damaged model						
4	50	124	500	5	1 1/2	u p t
* 9	50	111	300	5	2	u p
9	50	111	300	6	2	u p t
14	50	98	250	6	1 1/2	b
14	50	98	250	7	1 1/2	b t

NACA

REMARKS

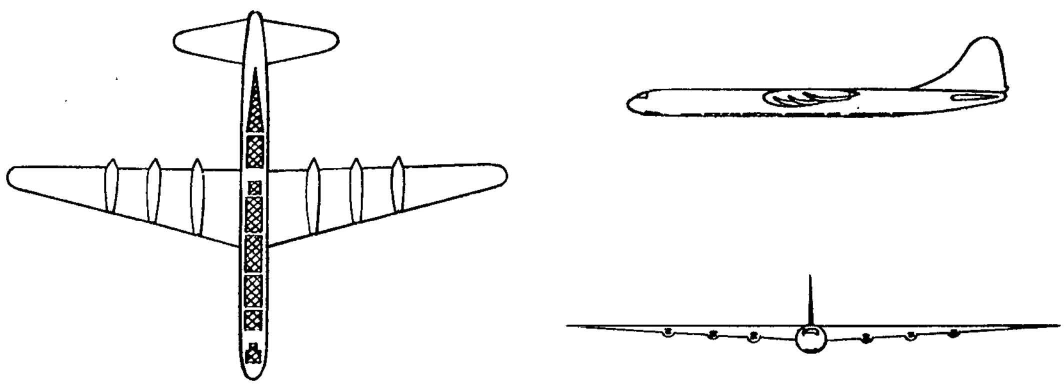
The most pronounced ditching characteristic of the B-35 model was its tendency to turn or yaw. Construction of the airplane is such that extensive damage is to be expected and it probably will be difficult to find ditching stations where crew members can adequately brace themselves and be reasonably sure of avoiding a large inrush of water. (See reference 14.)

TABLE X

SUMMARY OF MODEL DITCHING INVESTIGATION OF CONSOLIDATED VULTEE B-36 AIRPLANE

[Model scale, $\frac{1}{20}$ and $\frac{1}{30}$; gross weight, 255,000 lb; center-of-gravity location, 29 percent M.A.C.; all values full scale]

Damage simulated by removal of section (shaded areas on three view)



Landing attitude (deg)	Flap setting (deg)	Landing speed (knots)	Length of run (ft)	Maximum longitudinal deceleration (g)	Average longitudinal deceleration (g)	Motions of model
Undamaged 1/30-scale model						
1	40	124	1000	-	1/2	u h
1	40	124	1000	-	1/2	u s
5	40	106	650	-	1	h
9	0	119	650	-	1	h
9	40	95	1000	-	1/2	h
13	0	108	1000	-	1/2	p
13	40	87	650	-	1/2	h
Damaged 1/20-scale model						
1	40	124	-	4	-	b
* 9	40	95	-	2	-	h

REMARKS

The behavior of the model was generally good. No violent motions such as diving occurred, and the maximum longitudinal deceleration recorded was about 4g. (See reference 15.)

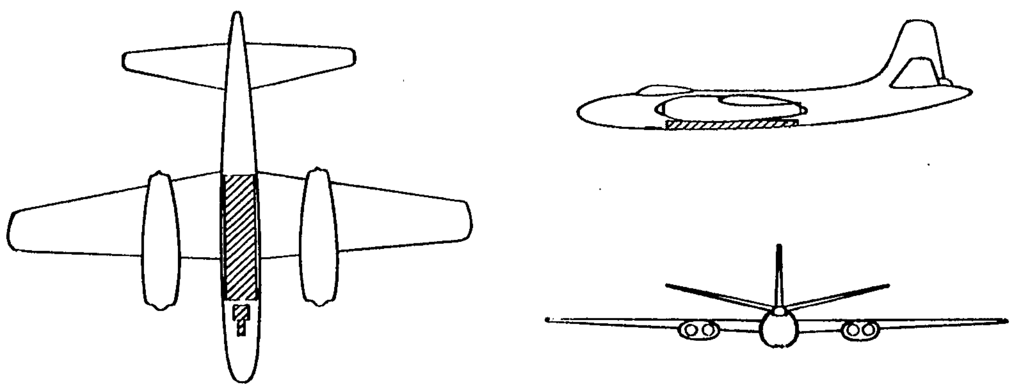
TABLE XI

SUMMARY OF MODEL DITCHING INVESTIGATION OF NORTH AMERICAN B-45 AIRPLANE

[Model scale, $\frac{1}{18}$; gross weight, 82,600 lb; center-of-gravity location, 29 percent M.A.C.; all values full scale]

(a) Without hydroflap

Damage simulated by removal of parts and covering of openings with aluminum sheet (shaded areas on three view)



Landing attitude (deg)	Flap setting (deg)	Landing speed (knots)	Length of run (ft)	Maximum longitudinal deceleration (g)	Average longitudinal deceleration (g)	Motions of model
Undamaged model						
2	40	131	950	1 1/2	1	u h
6	40	119	850	1	1/2	u h
Damaged model						
2	40	131	200	9 1/2	4	d_1
* 6	40	119	300	5	2	d_1

NACA

REMARKS

The scale-strength bomb-bay doors and nose-wheel doors consistently failed on the model. The dives that occurred were very violent. Recently published data have indicated that if the bulkhead and section aft of the bomb bay failed in a ditching diving may not occur. (See references 16 and 17.)

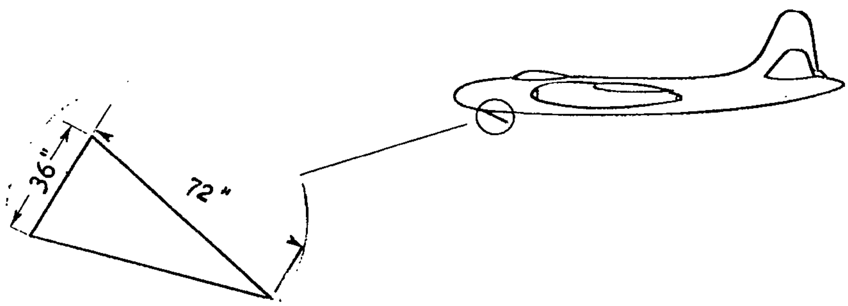
TABLE XI

SUMMARY OF MODEL DITCHING INVESTIGATION OF NORTH AMERICAN B-45 AIRPLANE - Concluded

[All values full scale]

(b) With hydroflap

Damage same as shown on three view. Hydroflap as indicated below.



Landing attitude (deg)	Flap setting (deg)	Landing speed (knots)	Length of run (ft)	Maximum longitudinal deceleration (g)	Average longitudinal deceleration (g)	Motions of model
2	40	131	720	3 1/2	1	s p
* 6	40	119	540	3 1/2	1	s p

REMARKS

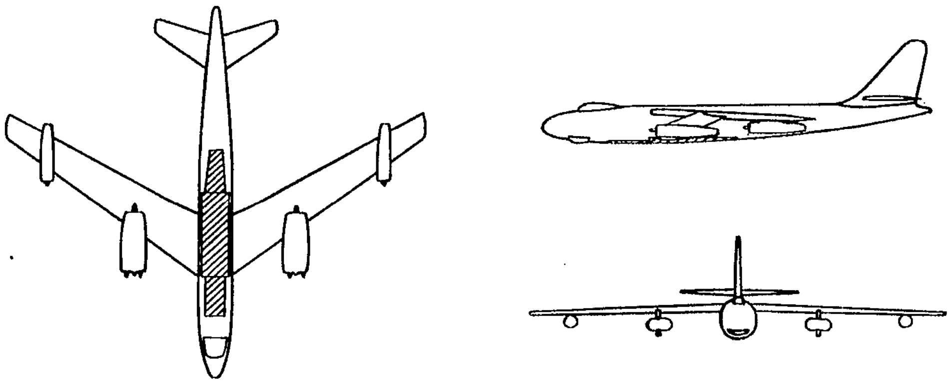
The hydroflap stopped the diving and reduced the deceleration. It also kept the nose-wheel doors from failing. (See reference 16.)

TABLE XII

SUMMARY OF MODEL DITCHING INVESTIGATION OF BOEING B-47 AIRPLANE

[Model scale, $\frac{1}{24}$; gross weight, 125,000 lb; center-of-gravity location, 20 percent M.A.C.; all values full scale]

Damage simulated by removal of parts and covering of openings with aluminum sheet (shaded areas on three view)



Landing attitude (deg)	Flap setting (deg)	Landing speed (knots)	Length of run (ft)	Maximum longitudinal deceleration (g)	Average longitudinal deceleration (g)	Motions of model
			Undamaged model			
5	35	134	650	2	1	u s p
10	0	155	700	3	1 1/2	h
10	35	120	650	2	1	h
15	35	115	550	1 1/2	1	h
			Damaged model			
5	35	134	650	3	1	b
* 10	35	120	550	2 1/2	1	h
15	35	115	450	3	1 1/2	b

REMARKS

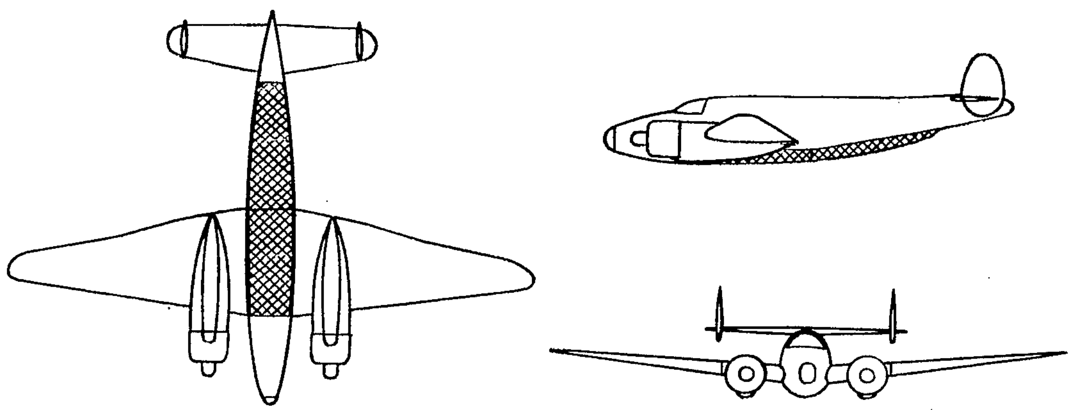
Additional tests with the nacelles attached at scale strength indicated that the nacelles will probably be torn off in a ditching but will have little or no effect on behavior. (See reference 18.)

TABLE XIII

SUMMARY OF MODEL DITCHING INVESTIGATION OF LOCKHEED PV AIRPLANE

[Model scale, $\frac{1}{11}$; gross weight, 26,500 lb; center-of-gravity location, 30 percent M.A.C.; all values full scale]

Damage simulated by removal of section (shaded areas in three view)



Landing attitude (deg)	Flap setting (deg)	Landing speed (knots)	Length of run (ft)	Maximum longitudinal deceleration (g)	Average longitudinal deceleration (g)	Motions of model
Undamaged model						
2	38	113	450	4	1	s p
7	0	122	650	-	1	s t
7	38	87	450	1 1/2	1	p
12	0	104	700	1	1	h
12	38	87	350	2	1	h
Damaged model						
2	38	122	400	-	1 1/2	s p
7	38	87	300	-	1	p
* 12	38	87	300	-	1	p

REMARKS

From examination of full-scale ditching reports on this airplane it is believed that the fuselage bottom section aft of the bomb bay will be torn away in a ditching with the results indicated above. If this section does not fail, violent dives would occur. (See reference 19.)

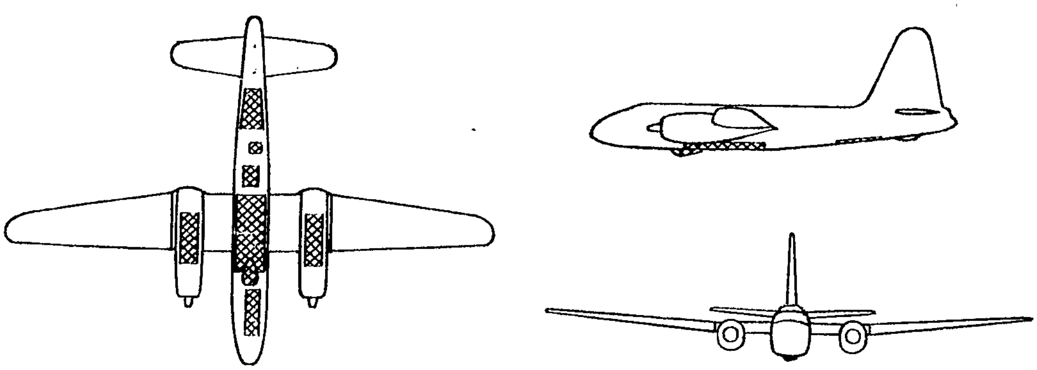
TABLE XIV

SUMMARY OF MODEL DITCHING INVESTIGATION OF LOCKHEED P2V AIRPLANE

[Model scale, $\frac{1}{16}$; gross weight, 45,000 lb; center-of-gravity location, 29 percent M.A.C.; all values full scale]

(a) Without hydroflap or hydro-skis

Damage simulated by removal of sections (shaded areas on three view)



Landing attitude (deg)	Flap setting (deg)	Landing speed (knots)	Length of run (ft)	Maximum longitudinal deceleration (g)	Average longitudinal deceleration (g)	Motions of model
Undamaged model						
2	32	89	400	2	1	u h
6	0	121	700	2	1	h
6	32	78	300	2	1	h
10	0	102	550	1 1/2	1	h
10	32	71	300	2	1	h
Damaged model						
2	32	89	150	6	2 1/2	d_1
* 6	32	78	150	4	2	d_1
10	32	71	100	3 1/2	2 1/2	d_1

REMARKS

Data obtained from the manufacturer indicated that the fuselage bottom is extremely weak so considerable damage would be expected with this airplane. The diving caused by simulated damage was very violent. (See reference 20.)

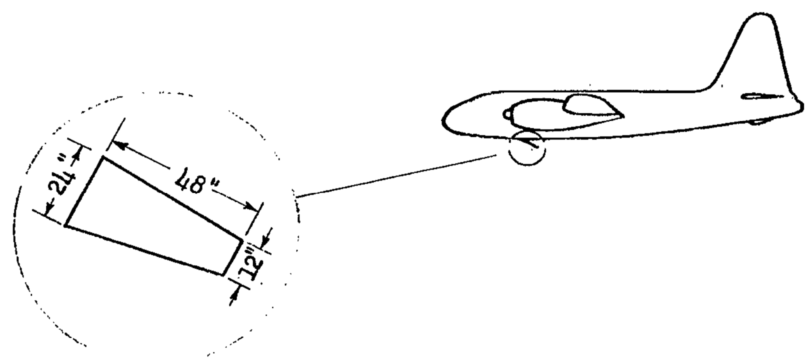
TABLE XIV

SUMMARY OF MODEL DITCHING INVESTIGATION OF LOCKHEED P2V AIRPLANE - Continued

[All values full scale]

(b) With hydroflap

Damage same as shown on three view except nose-wheel doors not removed. Hydroflap as indicated below.



Landing attitude (deg)	Flap setting (deg)	Landing speed (knots)	Length of run (ft)	Maximum longitudinal deceleration (g)	Average longitudinal deceleration (g)	Motions of model
2	32	89	450	3	1	p h
* 6	32	78	300	3 1/2	1	p h
10	32	71	250	4	1	p h

REMARKS

The location of the hydroflap on this airplane was critical. When located forward of the nose-wheel doors it did not stop the diving. (See reference 20.)

TABLE XIV

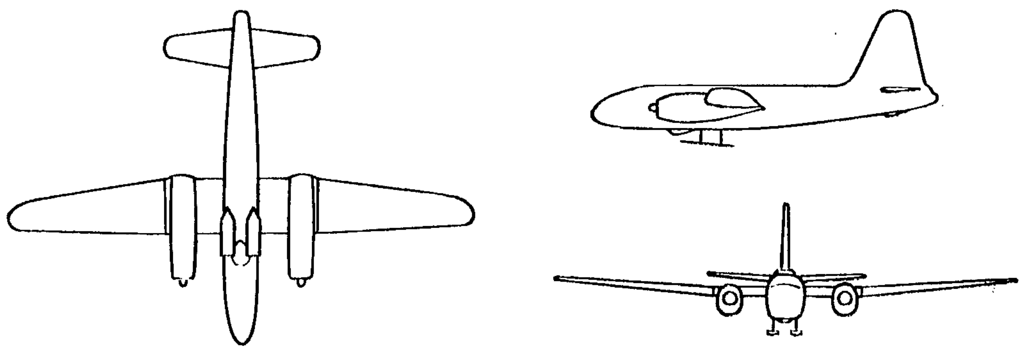
SUMMARY OF MODEL DITCHING INVESTIGATION OF LOCKHEED

P2V AIRPLANE - Concluded

[All values full scale]

(c) With twin hydro-skis

No damage simulated. Skis as shown below.



Landing attitude (deg)	Flap setting (deg)	Landing speed (knots)	Length of run (ft)	Maximum longitudinal deceleration (g)	Average longitudinal deceleration (g)	Motions of model
2	32	89	1350	1	1/2	h
6	32	78	950	-	1/2	h
10	32	71	500	1/2	1/2	h

REMARKS

The ditching behavior with the hydro-skis was very good. It is possible that critical damage can be eliminated from ditchings by using a hydro-ski ditching gear, thus greatly increasing the chances of survival and rescue. (See reference 37.)

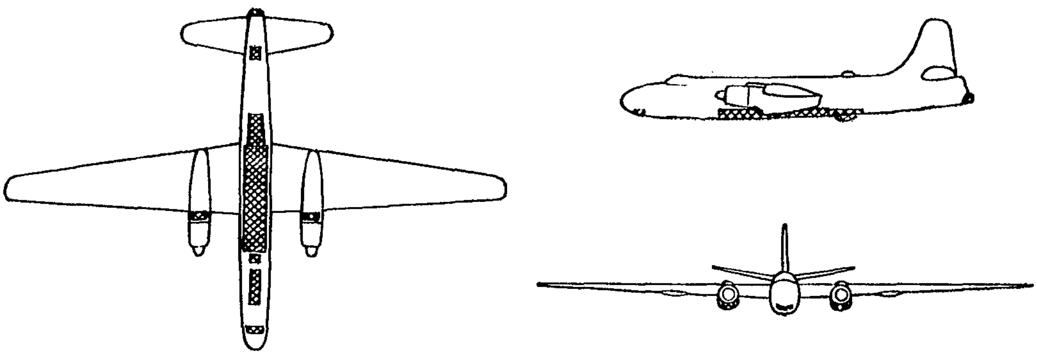
TABLE XV

SUMMARY OF MODEL DITCHING INVESTIGATION OF MARTIN P4M AIRPLANE

[Model scale, $\frac{1}{18}$; gross weight, 55,000 lb; center-of-gravity location, 22 percent M.A.C.; all values full scale]

(a) Without hydroflap

Damage simulated by removal of sections (shaded areas on three view)



Landing attitude (deg)	Flap setting (deg)	Landing speed (knots)	Length of run (ft)	Maximum longitudinal deceleration (g)	Average longitudinal deceleration (g)	Motions of model
Undamaged model						
1	40	98	300	-	1 1/2	h
7	0	108	400	-	1 1/2	p
7	40	88	300	-	1	p
13	0	98	300	-	1 1/2	h
13	40	82	300	-	1	h
Damaged model						
1	40	95	100	4 1/2	4	d_2
* 7	40	89	200	3	2	p
* 7	40	89	100	4 1/2	3 1/2	d_2
13	40	82	150	3 1/2	2	d_2
13	40	82	150	3 1/2	2	t

REMARKS

The behavior of the damaged model varied inconsistently. (See reference 21.)

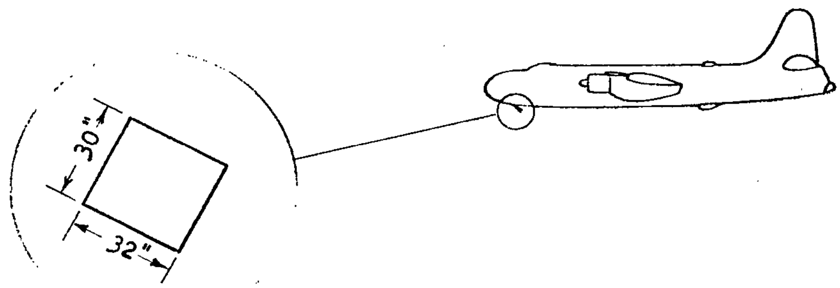
TABLE XV

SUMMARY OF MODEL DITCHING INVESTIGATION OF MARTIN P4M AIRPLANE - Concluded

[All values full scale]

(b) With hydroflap

Damage same as shown on three view. Navigator's escape hatch (open at an angle of 30° to the thrust line) used as hydroflap.



Landing attitude (deg)	Flap setting (deg)	Landing speed (knots)	Length of run (ft)	Maximum longitudinal deceleration (g)	Average longitudinal deceleration (g)	Motions of model
1	40	95	150	3	2 1/2	p
* 7	40	85	150	2 1/2	2	p
13	40	82	150	3	2	p

REMARKS

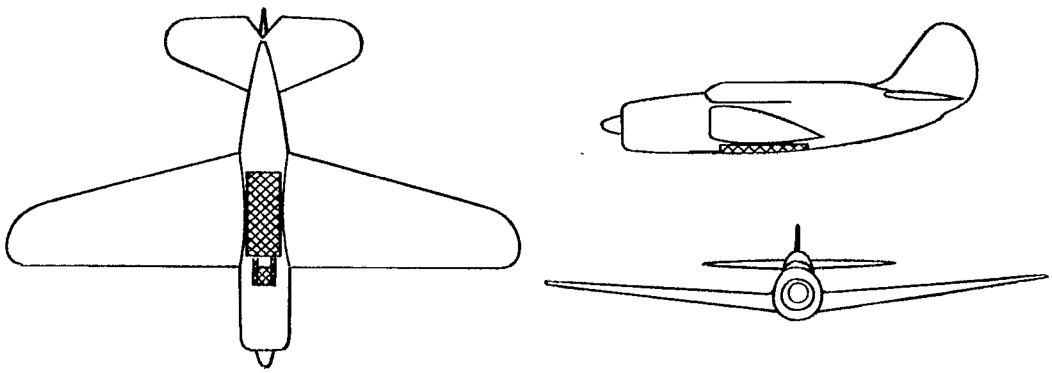
The hydroflap is recommended as a ditching aid on this airplane to stop the diving that sometimes occurred. It also reduced the decelerations slightly. (See reference 21.)

TABLE XVI

SUMMARY OF MODEL DITCHING INVESTIGATION OF CURTISS SB2C AIRPLANE

[Model scale, $\frac{1}{8}$; gross weight, 13,060 lb; center-of-gravity location, 30 percent M.A.C.; all values full scale]

Damage simulated by removal of sections (shaded areas on three view)



Landing attitude (deg)	Flap setting (deg)	Landing speed (knots)	Length of run (ft)	Maximum longitudinal deceleration (g)	Average longitudinal deceleration (g)	Motions of model
Damage as on three view						
2	30	113	150	8	4	d_1
2	60	104	100	5 1/2	5	d_1
2	60	104	-	-	-	s
8	0	113	400	6 1/2	1 1/2	s
8	0	113	-	-	-	p
8	30	95	200	5	2	d_1
8	60	87	150	7	2	d_1
8	60	87	-	-	-	s
15	0	87	200	4 1/2	1 1/2	d_1
15	0	87	-	-	-	b
15	30	78	150	5	2	d_1
15	60	69	200	4	1	d_1
15	60	69	-	-	-	s b

REMARKS

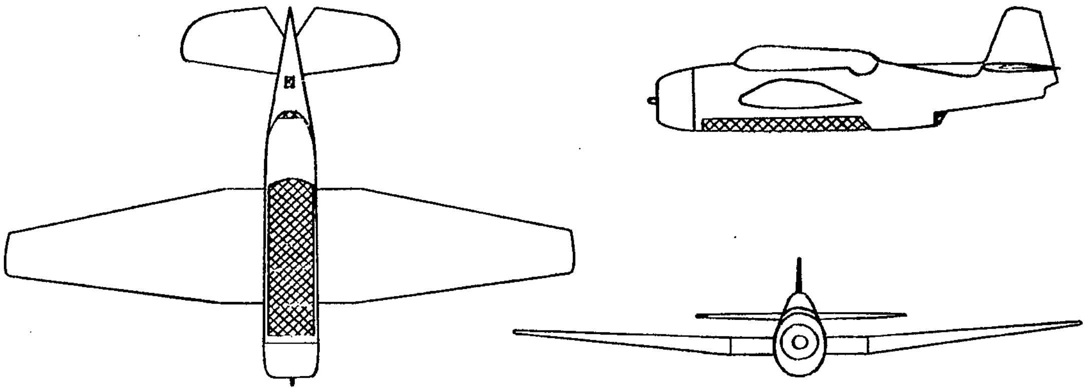
The landing flaps were very strong on this scout bomber. When they failed the model skipped or made a deep run; when they did not fail the model dived. (See reference 22.)

TABLE XVII

SUMMARY OF MODEL DITCHING INVESTIGATION OF GRUMMAN TBF AIRPLANE

[Model scale, $\frac{1}{9}$; gross weight, 13,795 lb; center-of-gravity location, 26 percent M.A.C.; all values full scale]

Damage simulated by removal of sections (shaded areas on three view)



Landing attitude (deg)	Flap setting (deg)	Landing speed (knots)	Length of run (ft)	Maximum longitudinal deceleration (g)	Average longitudinal deceleration (g)	Motions of model
Undamaged model						
3	45	80	500	-	1/2	p h
7	0	86	550	-	1/2	s h
7	45	76	400	2	1/2	p h
11	0	85	500	1 1/2	1/2	p h
11	45	68	450	1	1/2	p h
Damaged model						
3	45	77	100	4 1/2	2 1/2	d_1
* 7	45	76	150	3 1/2	1 1/2	d_1
11	45	66	100	-	2	d_1

REMARKS

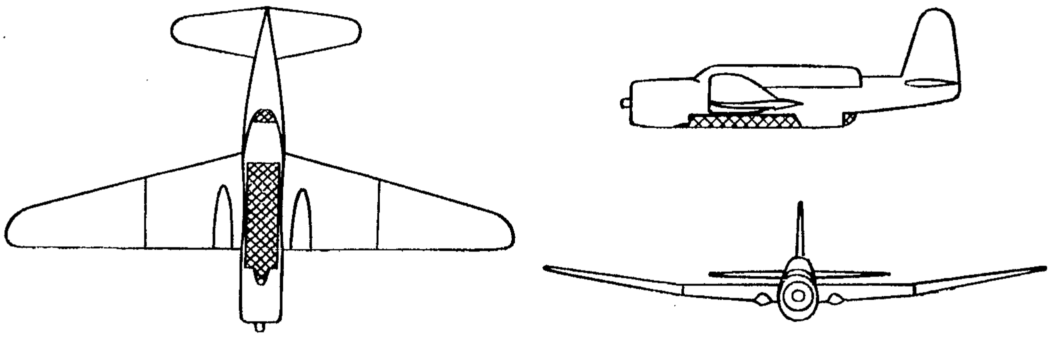
Full-scale reports have indicated that all personnel aboard this airplane have a good chance to survive a ditching and if the radioman moves to the upper part of the fuselage his chances will be improved. (Reference unpublished.)

TABLE XVIII

SUMMARY OF MODEL DITCHING INVESTIGATION OF CHANCE VOUGHT TBU AIRPLANE

[Model scale, $\frac{1}{9}$; gross weight, 16,925 lb; center-of-gravity location, 32 percent M.A.C.; all values full scale]

Damage simulated by removal of sections (shaded areas on three view)



Landing attitude (deg)	Flap setting (deg)	Landing speed (knots)	Length of run (ft)	Maximum longitudinal deceleration (g)	Average longitudinal deceleration (g)	Motions of model
Undamaged model						
2	50	96	600	-	1/2	s
7	0	108	800	-	1/2	s
7	50	85	500	-	1/2	s
12	0	89	550	-	1/2	p
12	50	78	550	-	1/2	p
18	0	85	500	-	1/2	s p
18	50	71	450	-	1/2	p h
Damaged model						
2	50	100	80	-	5 1/2	d_1
7	50	87	100	-	3 1/2	d_1
* 12	50	78	100	-	2 1/2	d_1
18	50	71	100	-	2	d_1

REMARKS

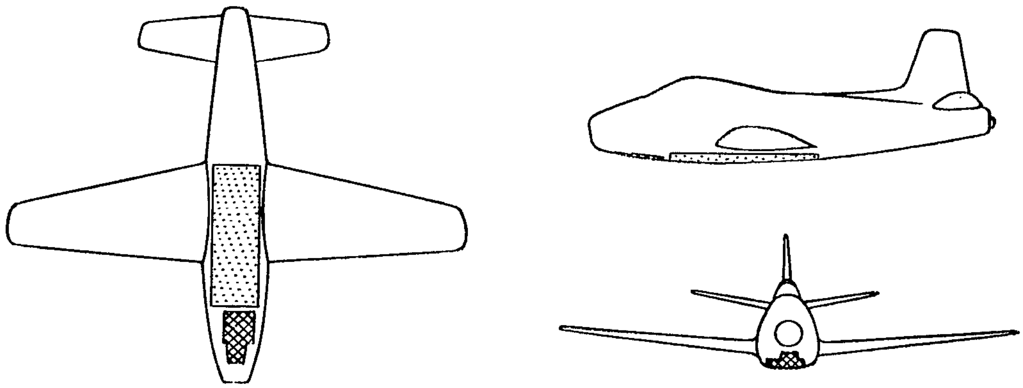
This airplane closely resembles the TBF airplane. The ditching behavior of the models was similar, but the higher landing speeds of the TBU give higher average decelerations. (Reference unpublished.)

TABLE XIX

SUMMARY OF MODEL DITCHING INVESTIGATION OF NORTH AMERICAN FJ AIRPLANE

[Model scale, $\frac{1}{10}$; gross weight, 12,151 lb; center-of-gravity location, 23 percent M.A.C.; all values full scale]

Damage simulated be removal of sections and crumpling of other sections (shaded areas on three view).



Landing attitude (deg)	Flap setting (deg)	Landing speed (knots)	Length of run (ft)	Maximum longitudinal deceleration (g)	Average longitudinal deceleration (g)	Motions of model
Undamaged model						
2	40	128	650	9 1/2	1	u s d_1
8	40	104	1000	4	1/2	u s h
12	0	118	900	6	1/2	u s p
12	40	94	700	2 1/2	1/2	u s p h
Damaged model						
2	40	128	900	5	1	u s h
8	40	104	700	3	1/2	u s p h
* 12	40	94	600	2 1/2	1/2	h u p h

REMARKS

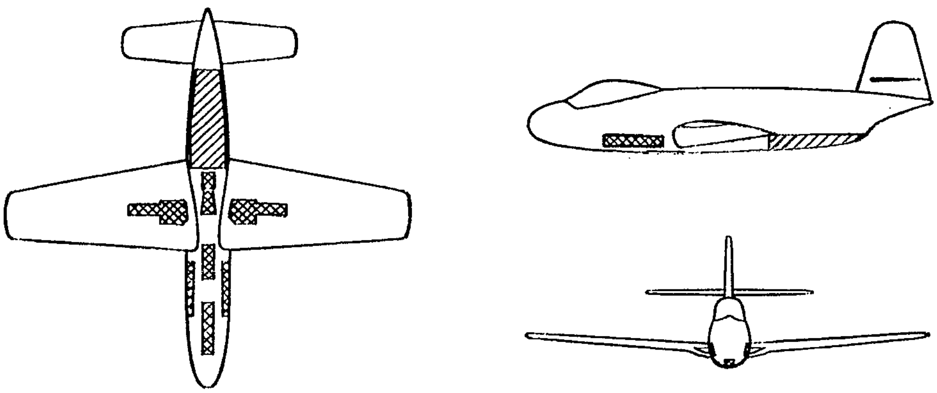
The undamaged XFJ model trimmed up and skipped violently when it contacted the water. Simulation of damage improved the ditching behavior by reducing the trimming up and skipping. (See reference 23.)

TABLE XX

SUMMARY OF MODEL DITCHING INVESTIGATION OF CHANCE VOUGHT F6U AIRPLANE

[Model scale, $\frac{1}{8}$; gross weight, 9706 lb; center-of-gravity location, 31 percent M.A.C.; all values full scale]

Damage simulated by use of scale-strength sections and removal of other sections (shaded areas on three view).



Landing attitude (deg)	Flap setting (deg)	Landing speed (knots)	Length of run (ft)	Maximum longitudinal deceleration (g)	Average longitudinal deceleration (g)	Motions of model
Undamaged model						
4	27	124	500	2	1 1/2	u s p
8	27	107	550	1	1	u s p
12	27	97	400	2	1	u p
Damaged model						
4	27	124	200	9	3 1/2	p d_2
8	27	107	150	10	3 1/2	d_1
* 12	27	97	100	7	4	d_1

REMARKS

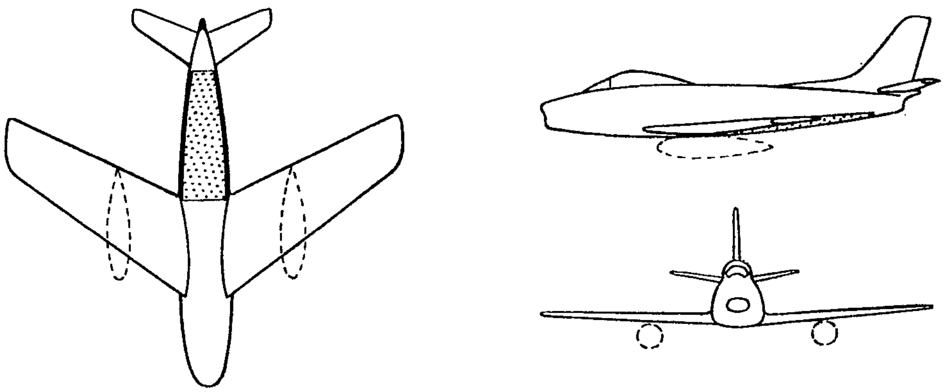
The trimming up and diving of this model was extremely severe. The pilot should make sure that the safety harness is securely fastened in order to withstand the decelerations. (See reference 24.)

TABLE XXI

SUMMARY OF MODEL DITCHING INVESTIGATION OF NORTH AMERICAN F-86 AIRPLANE

[Model scale, $\frac{1}{10}$; gross weight, 13,311 lb; center-of-gravity location, 22 percent M.A.C.; all values full scale]

Damage simulated by crumpled bottom.(shaded areas on three view)



Landing attitude (deg)	Flap setting (deg)	Landing speed (knots)	Length of run (ft)	Maximum longitudinal deceleration (g)	Average longitudinal deceleration (g)	Motions of model
Undamaged model						
4	38	132	300	8	2 1/2	d_1
9	38	109	800	1	1/2	h
14	0	113	700	2 1/2	1	p s
14	38	98	650	1 1/2	1/2	h
Damaged model						
4	38	132	200	7 1/2	4	d_1
9	38	109	600	3	1	h
* 14	38	98	600	3	1/2	h

REMARKS

Extreme care should be taken to avoid the violent dive at the low attitude. The wing tanks on this airplane are located under the wing and should be jettisoned before ditching. (See reference 25.)

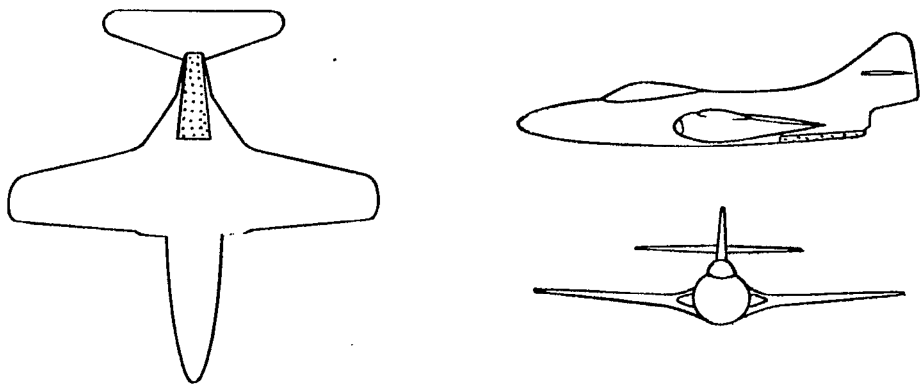
TABLE XXII

SUMMARY OF MODEL DITCHING INVESTIGATION OF GRUMMAN F9F AIRPLANE

[Model scale, $\frac{1}{10}$; gross weight, 12,100 lb; center-of-gravity location, 27 percent M.A.C.; all values full scale]

(a) Without hydroflap

Damage simulated by crumpled bottom. (shaded areas on three view)



Landing attitude (deg)	Flap setting (deg)	Landing speed (knots)	Length of run (ft)	Maximum longitudinal deceleration (g)	Average longitudinal deceleration (g)	Motions of model
			Undamaged model			
4	inboard 20 outboard 55	133	740	5	1	s p
8	inboard 20 outboard 55	115	760	3	1	s p
12	inboard 20 outboard 55	102	590	2	1	s p
			Damaged model			
4	inboard 20 outboard 55	133	760	5	1	s p
8	inboard 20 outboard 55	115	685	3	1	s p
* 12	inboard 20 outboard 55	102	700	2	1/2	s p

REMARKS

This model made rather long runs with severe skipping. (See reference 26.)

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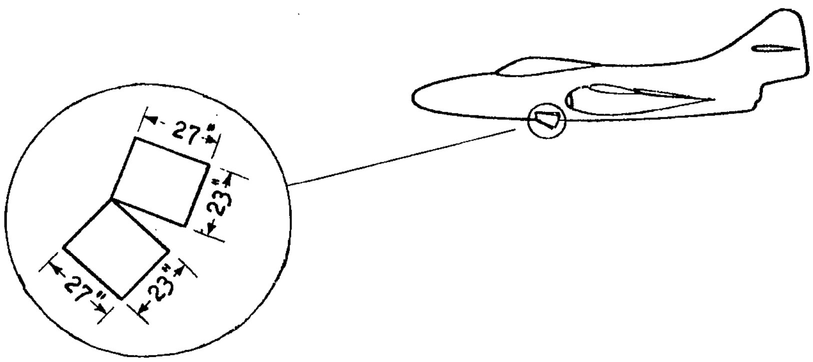
TABLE XXII

SUMMARY OF MODEL DITCHING INVESTIGATION OF GRUMMAN F9F AIRPLANE - Concluded

[All values full scale]

(b) With hydroflap

Damage same as shown on three view. Speed brake (open at angle of 30° to thrust line) used as hydroflap.



Landing attitude (deg)	Flap setting (deg)	Landing speed (knots)	Length of run (ft)	Maximum longitudinal deceleration (g)	Average longitudinal deceleration (g)	Motions of model
8	inboard 20 outboard 55	115	765	2	1	s p
* 12	inboard 20 outboard 55	102	595	2	1	p s p

REMARKS

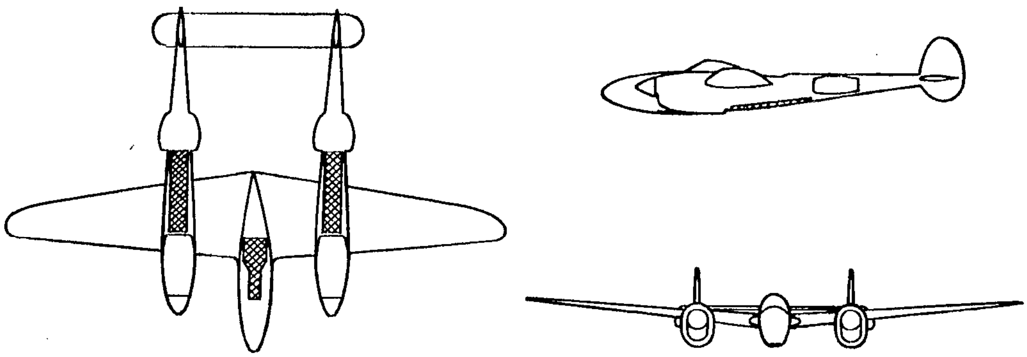
The severity of the skipping was reduced by using the hydroflap. (See reference 26.)

TABLE XXIII

SUMMARY OF MODEL DITCHING INVESTIGATION OF LOCKHEED P-38 AIRPLANE

[Model scale, $\frac{1}{9}$; gross weight, 14,900 lb; center-of-gravity location, 28 percent M.A.C.; all values full scale]

Damage simulated by removal of sections (shaded areas on three view)



Landing attitude (deg)	Flap setting (deg)	Landing speed (knots)	Length of run (ft)	Maximum longitudinal deceleration (g)	Average longitudinal deceleration (g)	Motions of model
Undamaged model						
5	37	100	250	6	2	s
9	0	115	250	-	2 1/2	b
9	37	88	200	4	1 1/2	s o
13	0	100	250	8	2	b
13	37	79	200	-	1 1/2	s
Damaged model						
2	37	113	100	-	5 1/2	s d_2
5	37	100	200	-	2	s
* 9	37	88	200	-	1 1/2	s
*13	37	79	250	-	1	s

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REMARKS

The landing speed was the most important variable affecting performance. At the high speeds the highest deceleration as well as the most violent behaviors were encountered. A tail-down attitude (from 9° to 13°) was recommended. (See reference 27.)

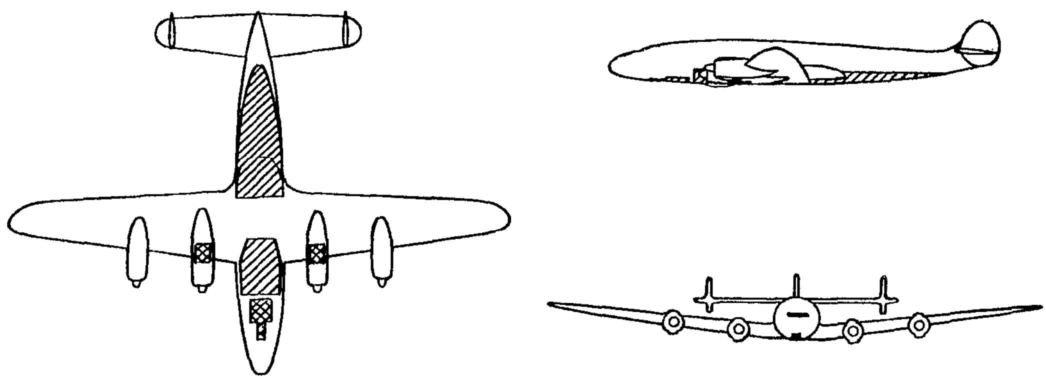
TABLE XXIV

SUMMARY OF MODEL DITCHING INVESTIGATION OF LOCKHEED CONSTELLATION AIRPLANE

[Model scale, $\frac{1}{18}$; gross weight, 83,000 lb; center-of-gravity location, 25 percent M.A.C.; all values full scale]

(a) Without Speedpak or hydro-ski

Damage simulated by use of scale-strength sections and removal of other sections (shaded areas on three view)



Landing attitude (deg)	Flap setting (deg)	Landing speed (knots)	Length of run (ft)	Maximum longitudinal deceleration (g)	Average longitudinal deceleration (g)	Motions of model
Undamaged model						
4	0	148	900	6	1	s h
4	40	91	250	4	1 1/2	d_2
9	0	115	600	2	1	u h
9	40	79	400	4	1/2	b
12	0	102	600	1	1	h
12	40	74	250	3	1	b
Damaged model						
4	40	91	200	4	2	b d_2
* 9	40	79	350	3	1	b d_2
12	40	74	200	4	1	h b

REMARKS

The fuselage will be damaged and leak substantially but in calm water it probably will not flood rapidly. (See reference 28.)

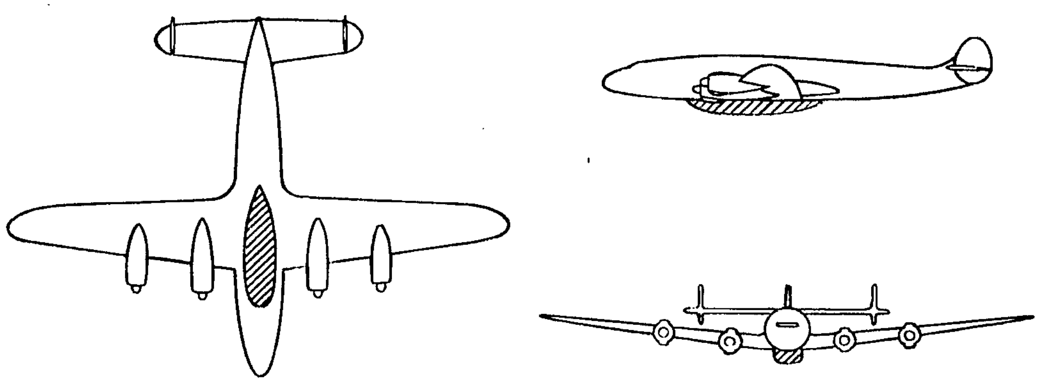
TABLE XXIV

SUMMARY OF MODEL DITCHING INVESTIGATION OF LOCKHEED CONSTELLATION AIRPLANE - Continued

[Model scale, $\frac{1}{18}$; gross weight airplane, 83,000 lb; gross weight Speedpak, 10,000 lb; center-of-gravity location, 25 percent M.A.C.; all values full scale]

(b) With Speedpak

Model undamaged - scale-strength Speedpak attached as shown below



Landing attitude (deg)	Flap setting (deg)	Landing speed (knots)	Length of run (ft)	Maximum Longitudinal deceleration (g)	Average longitudinal deceleration (g)	Motions of model
4	40	95	650	-	1/2	h d_2
* 9	40	85	500	1 1/2	1/2	h b
12	40	78	250	2	1	h b

REMARKS

The Speedpak bottom was damaged considerably and evidently absorbed some of the landing loads. The decelerations were less and the behavior of the model was more favorable. The Speedpak also protected the fuselage bottom. (See reference 29.)

TABLE XXIV

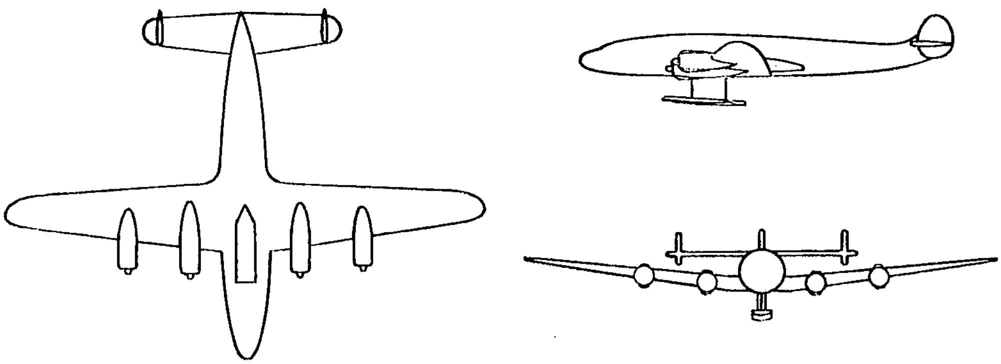
SUMMARY OF MODEL DITCHING INVESTIGATION OF LOCKHEED

CONSTELLATION AIRPLANE - Concluded

[All values full scale]

(c) With a hydro-ski

No damage simulated. Ski as shown below.



Landing attitude (deg)	Flap setting (deg)	Landing speed (knots)	Length of run (ft)	Maximum longitudinal deceleration (g)	Average longitudinal deceleration (g)	Motions of model
4	40	91	1220	1/2	1/2	h
9	40	79	720	-	1/2	h p

REMARKS

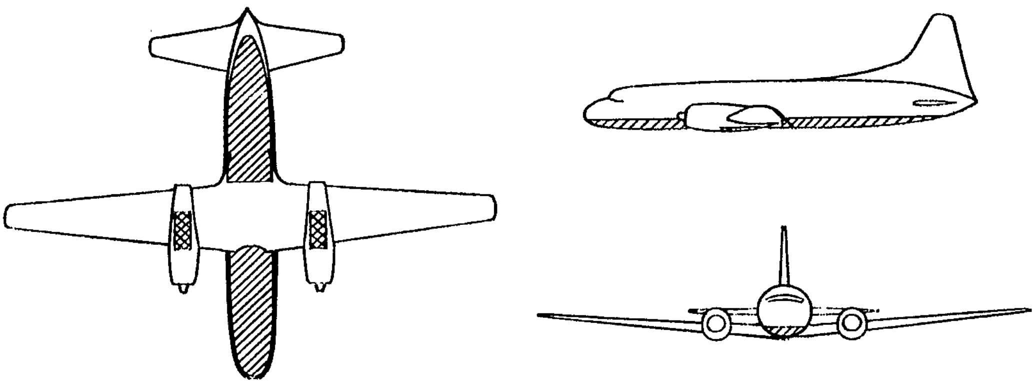
The ditching behavior with the hydro-ski was very good. It is possible that critical damage can be eliminated from ditchings by using a hydro-ski ditching gear, thus greatly increasing the chances of survival and rescue. (See reference 37.)

TABLE XXV

SUMMARY OF MODEL DITCHING INVESTIGATION OF CONVAIR-LINER AIRPLANE

[Model scale, $\frac{1}{15}$; gross weight, 43,500 lb; center-of-gravity location, 22 percent M.A.C.; all values full scale]

Damage simulated by use of scale-strength sections and removal of other sections (shaded areas on three view)



Landing attitude (deg)	Flap setting (deg)	Landing speed (knots)	Length of run (ft)	Maximum longitudinal deceleration (g)	Average longitudinal deceleration (g)	Motions of model
Undamaged model						
1	0	164	850	4	1 1/2	u h
1	39	100	350	5	1 1/2	u h
5	0	122	650	3	1	u h
5	39	88	400	1 1/2	1	h
9	0	105	600	3 1/2	1	h
9	39	82	400	1	1/2	h
Damaged model						
5	0	122	250	8	2 1/2	h b
5	39	88	300	3 1/2	1	h
9	0	105	300	6	1 1/2	h
* 9	39	82	300	3	1	h

REMARKS

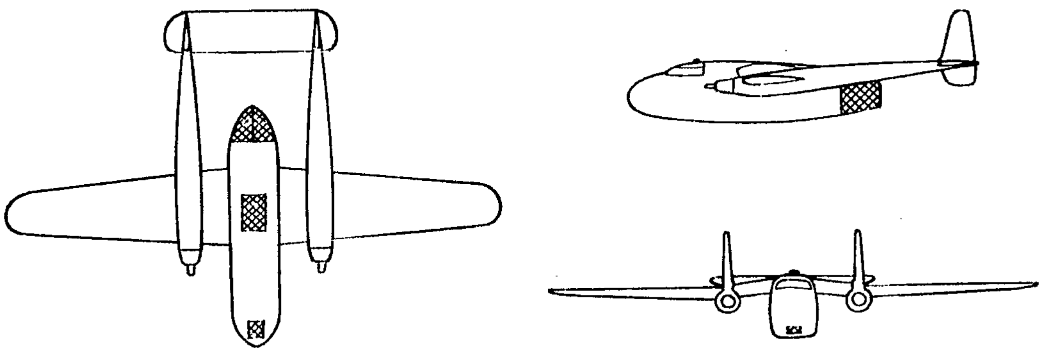
The landing flaps were an important factor in the ditching behavior of this model. Failure of the scale-strength flaps was simulated by the flaps rotating up or being torn from the model. When the flaps rotated up on failing, the model dived; but when the flaps were torn away, the model performed as indicated above. (See reference 30.)

TABLE XXVI

SUMMARY OF MODEL DITCHING INVESTIGATION OF FAIRCHILD C-82 AIRPLANE

[Model scale, $\frac{1}{15}$; gross weight, 50,000 lb; center-of-gravity location, 25 percent M.A.C.; all values full scale]

Damage simulated by removal of sections (shaded areas on three view)



Landing attitude (deg)	Flap setting (deg)	Landing speed (knots)	Length of run (ft)	Maximum longitudinal deceleration (g)	Average longitudinal deceleration (g)	Motions of model
Undamaged model						
2	40	109	700	1	1	u s p
7	40	90	300	2	1	u b
12	40	78	350	1	1	u b
Damaged model						
2	40	109	450	2 1/2	1	u b
7	40	90	350	2	1	b
* 12	40	78	300	1	1	b

REMARKS

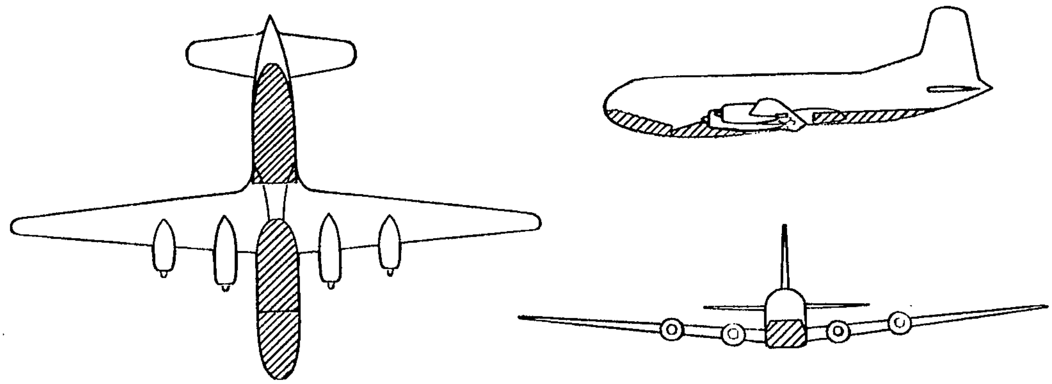
The undamaged model trimmed up considerably when it contacted the water. Damage to the fuselage bottom greatly reduced the trimming up and caused the cargo compartment to flood rapidly, making this a very hazardous ditching station. (See reference 31.)

TABLE XXVII

SUMMARY OF MODEL DITCHING INVESTIGATION OF DOUGLAS C-124 AIRPLANE

[Model scale, $\frac{1}{24}$; gross weight, 175,000 lb; center-of-gravity location, 27 percent M.A.C.; all values full scale]

Damage simulated by use of scale-strength sections (shaded areas on three view)



Landing attitude (deg)	Flap setting (deg)	Landing speed (mph)	Length of run (ft)	Maximum longitudinal deceleration (g)	Average longitudinal deceleration (g)	Motions of model
Undamaged model						
2	40	109	750	2	1/2	u h
7	0	157	1150	2	1	u h
7	40	96	800	1	1/2	u h
12	0	123	900	2	1/2	h
12	40	91	700	2 1/2	1/2	h
Damaged model						
2	40	109	550	4	1	h
*7	40	96	500	2 1/2	1	h
12	40	91	500	4 1/2	1	p

NACA

REMARKS

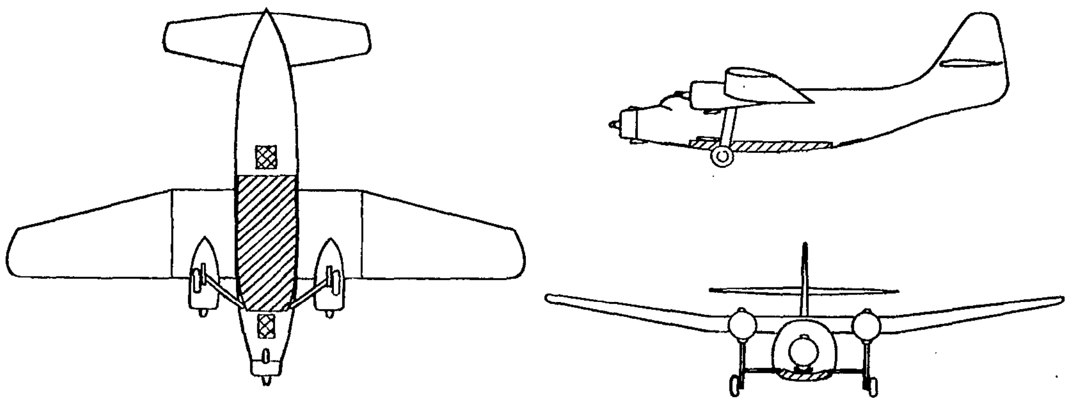
The large clamshell doors in the nose of this airplane and the unusual shape of the fuselage bottom forward of the wing were of particular interest. With the scale-strength sections installed only slight damage occurred to the clamshell doors and aft fuselage bottom, but considerable damage was sustained to the region just forward of the wing. However, the high location of the main floor should provide adequate ditching stations. (See reference 32.)

TABLE XXVIII

SUMMARY OF MODEL DITCHING INVESTIGATION OF NORTHROP C-125 AIRPLANE

[Model scale, $\frac{1}{14}$; gross weight, 35,123 lb; center-of-gravity location, 31 percent M.A.C.; all values full scale]

Damage simulated by use of scale-strength sections and removal of other sections (shaded areas on three view)



Landing attitude (deg)	Flap setting (deg)	Landing speed (knots)	Length of run (ft)	Maximum longitudinal deceleration (g)	Average longitudinal deceleration (g)	Motions of model
			Undamaged model			
0	55	64	150	2 1/2	1	d_1
4	0	102	200	5	2 1/2	f
4	55	60	200	2	1	d_2
8	0	87	150	4	2	d_1
8	55	56	150	2	1	d_2
			Damaged model			
0	55	64	150	4	1	d_1
4	55	60	150	2	1	d_2
* 8	55	56	150	2	1	d_2

REMARKS

The fixed landing gear on this model caused the diving and flipping over. When the gear was removed the model either ran smoothly or skipped and porpoised. (See reference 33.)

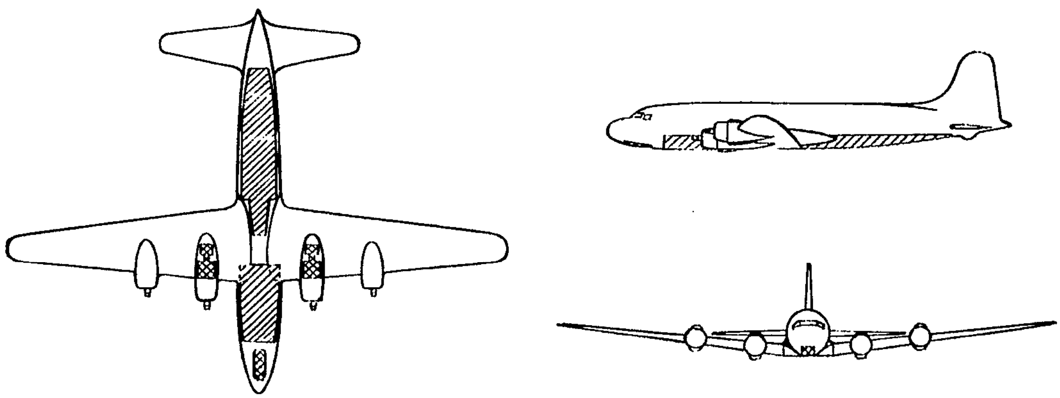
TABLE XXIX

SUMMARY OF MODEL DITCHING INVESTIGATION OF DOUGLAS DC-4 AIRPLANE

[Model scale, $\frac{1}{16}$; gross weight, 72,000 lb; center-of-gravity location, 28 percent M.A.C.; all values full scale]

(a) Without hydro-skis

Damage simulated by use of scale-strength sections and removal of other sections (shaded areas on three view)



Landing attitude (deg)	Flap setting (deg)	Landing speed (knots)	Length of run (ft)	Maximum longitudinal deceleration (g)	Average longitudinal deceleration (g)	Motions of model
Undamaged model						
2	50	98	650	2	1/2	h
7	50	87	600	1	1/2	h
12	50	79	450	1 1/2	1/2	h
Damaged model						
7	50	87	200	6	1 1/2	b
* 12	50	79	250	4 1/2	1	b

REMARKS

The damage sustained by the scale-strength sections was not severe. The airplane will leak but should not flood rapidly. (See reference 34.)

TABLE XXIX

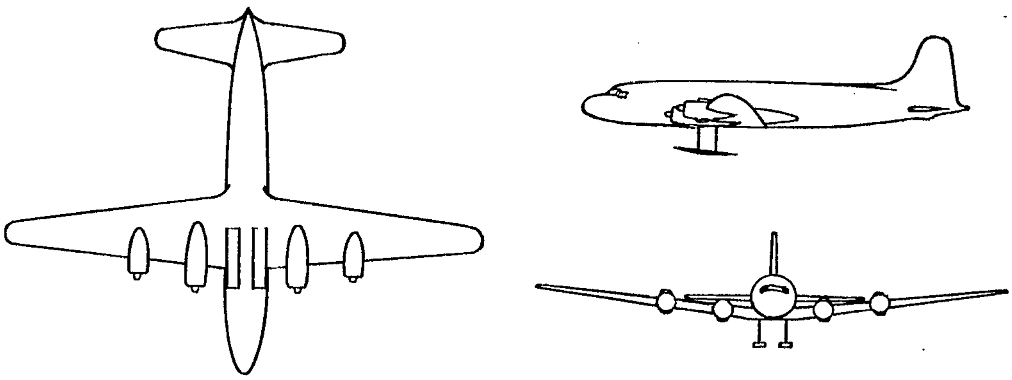
SUMMARY OF MODEL DITCHING INVESTIGATION OF DOUGLAS

DC-4 AIRPLANE - Concluded

[All values full scale]

(b) With hydro-skis

No damage simulated. Hydro-skis as shown below.



Landing attitude (deg)	Flap setting (deg)	Landing speed (knots)	Length of run (ft)	Maximum longitudinal deceleration (g)	Average longitudinal deceleration (g)	Motions of model
2	50	95	1300	-	1/2	h
7	50	88	750	-	1/2	h

REMARKS

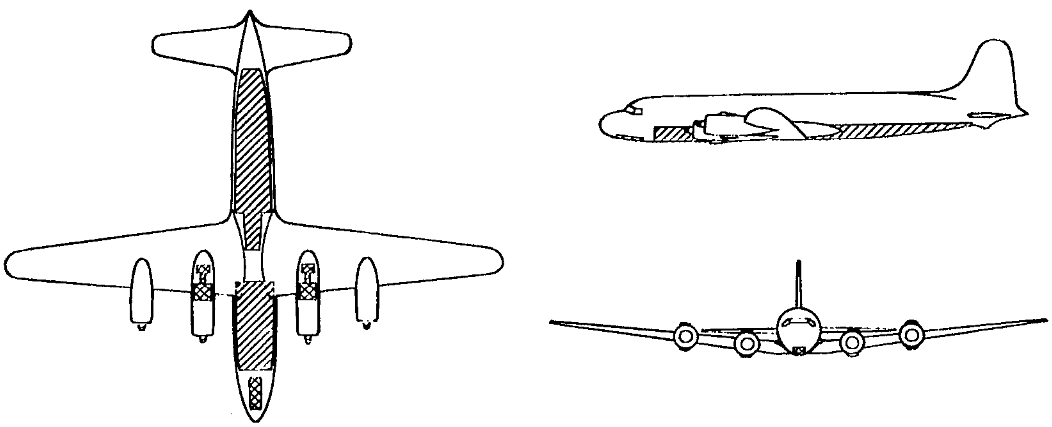
The ditching behavior with the hydro-skis was very good. It is possible that critical damage can be eliminated from ditchings by using a hydro-ski ditching gear, thus greatly increasing the chances of survival and rescue. (See reference 37.)

TABLE XXX

SUMMARY OF MODEL DITCHING INVESTIGATION OF DOUGLAS DC-6 AIRPLANE

[Model scale, $\frac{1}{16}$; gross weight, 84,000 lb; center-of-gravity location, 28 percent M.A.C.; all values full scale]

Damage simulated by use of scale-strength sections and removal of other sections (shaded areas on three view)



Landing attitude (deg)	Flap setting (deg)	Landing speed (knots)	Length of run (ft)	Maximum longitudinal deceleration (g)	Average longitudinal deceleration (g)	Motions of model
Undamaged model						
2	50	106	700	3	1/2	h
7	50	94	600	1	1/2	h
12	0	109	550	2	1	h
12	50	85	450	1 1/2	1/2	h
Damaged model						
7	50	94	250	5	1 1/2	b
* 12	50	85	250	3 1/2	1 1/2	b

NACA

REMARKS

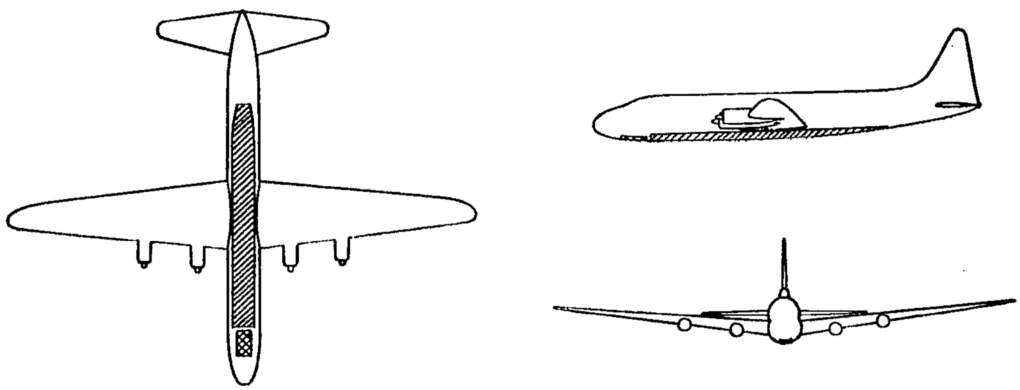
The damage sustained by the scale-strength sections was not severe. The airplane will leak but should not flood rapidly. (See reference 34.)

TABLE XXXI

SUMMARY OF MODEL DITCHING INVESTIGATION OF LOCKHEED R60 AIRPLANE

[Model scale, $\frac{1}{24}$; gross weight, 160,000 lb; center-of-gravity location, 40 percent M.A.C.; all values full scale]

Damage simulated by use of scale-strength sections and removal of other sections (shaded areas on three view)



Landing attitude (deg)	Flap setting (deg)	Landing speed (knots)	Length of run (ft)	Maximum longitudinal deceleration (g)	Average longitudinal deceleration (g)	Motions of model
Undamaged model						
1	45	90	450	1	1	u h
5	0	115	800	2	1/2	h
5	45	79	450	1/2	1/2	u h
9	0	96	600	1	1/2	h
9	45	72	450	1	1/2	h
Damaged model						
1	45	90	300	2 1/2	1	b
* 5	45	79	300	2	1	b h
9	45	72	300	2	1	b

REMARKS

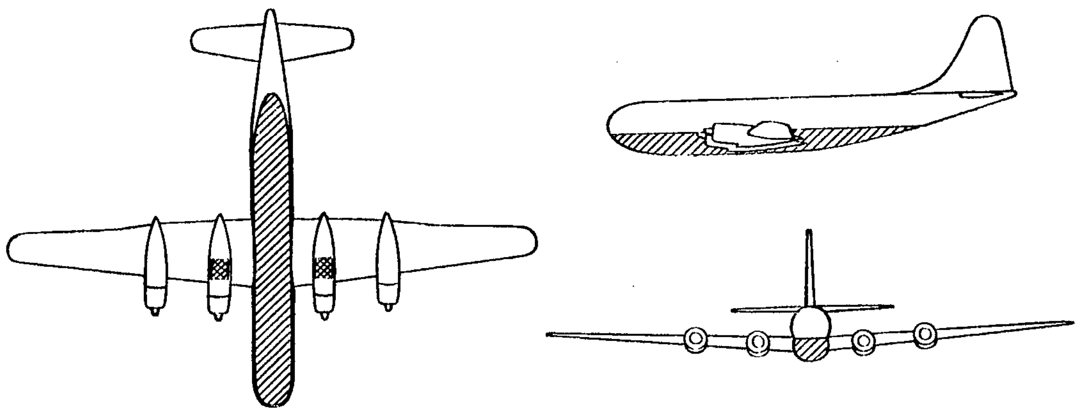
The scale-strength sections did not sustain severe damage. The main damage usually occurred near the part of the fuselage that contacted the water first. It appears likely that the cargo floor will not fail and that the interior of the airplane will be relatively safe in a ditching. (See reference 35.)

TABLE XXXII

SUMMARY OF MODEL DITCHING INVESTIGATION OF BOEING STRATOCRUISER AIRPLANE

[Model scale, $\frac{1}{20}$; gross weight, 130,000 lb; center-of-gravity location, 25 percent M.A.C.; all values full scale]

Damage simulated by use of scale-strength sections and removal of other sections (shaded areas on three view)



Landing attitude (deg)	Flap setting (deg)	Landing speed (knots)	Length of run (ft)	Maximum longitudinal deceleration (g)	Average longitudinal deceleration (g)	Motions of model
Undamaged model						
3	45	109	650	2	1	u h
6	45	102	500	2	1	u h
9	0	129	800	3	1	u p
9	45	97	450	2	1	u o h
Damaged model						
3	45	109	400	3	1 1/2	h
* 6	45	102	400	4	1	p h
9	45	97	350	4	1	b h

REMARKS

The scale-strength sections sustained some damage indicating that the lower compartment of this airplane will probably fill with water. However, the strong cargo floor should provide protection for the upper deck and the low wing should provide enough buoyancy to give personnel time to escape. (See reference 36.)

[redacted]

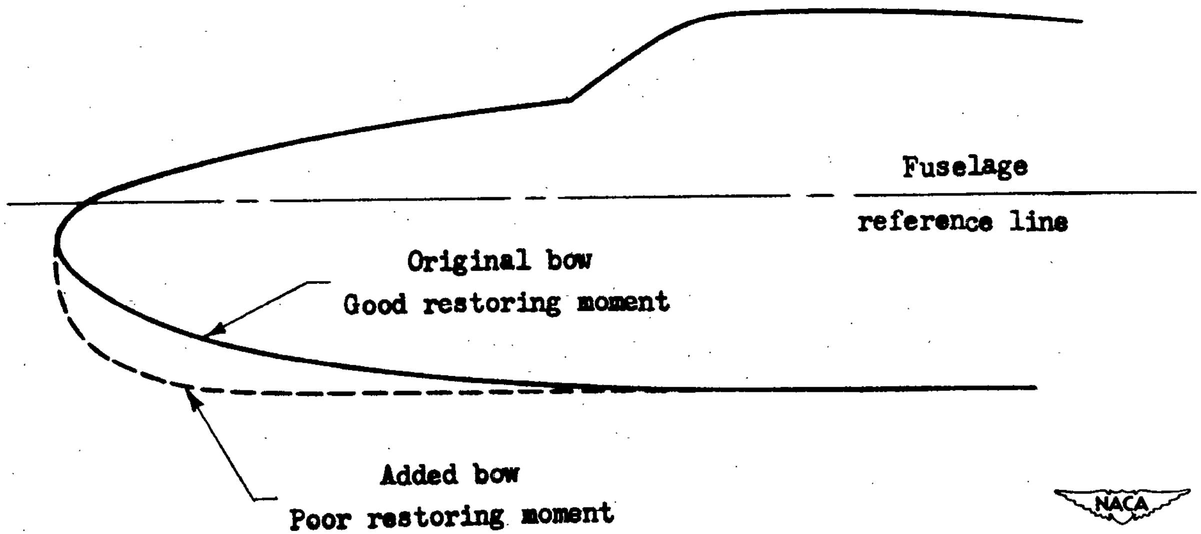


Figure 1.- Effect of bow longitudinal curvature.

[redacted]